Tau mass measurement at BESIII

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On behalf of BESIII collaboration

The 15th international workshop
on tau lepton physics

Outline

- Motivation
- BEPCII and BESIII
- Beam energy measurement system
- Data taking scenario
- Tau mass measurement at BESIII
- Summary

Motivation

- M_τ is a fundamental parameter of the standard model

  e,μ: $\Delta m/m \sim 10^{-8}$, τ: $\Delta m/m \sim 9.0 \times 10^{-5}$

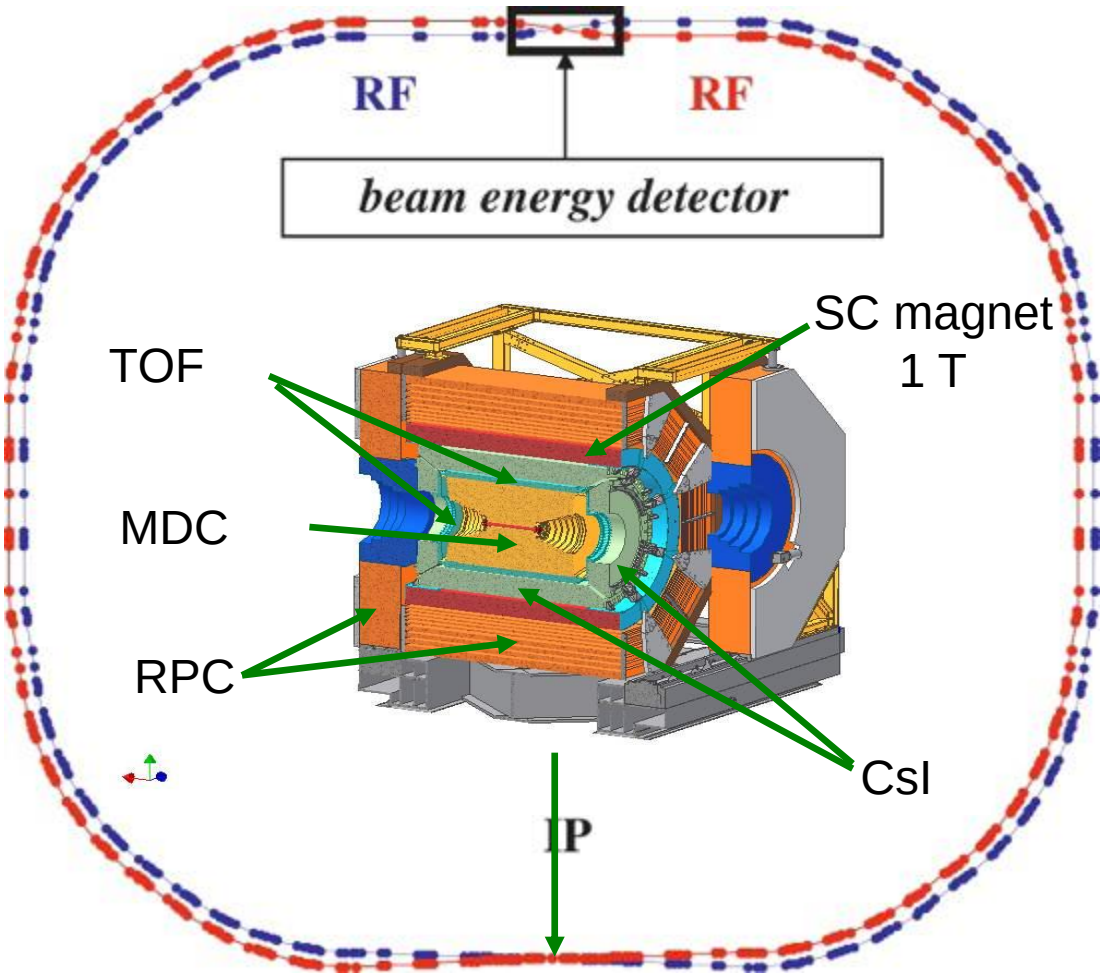
- Lepton universality test:

$$\left(\frac{G_\tau}{G_\mu}\right)^2 = \frac{\tau_\mu}{\tau_\tau}\left(\frac{m_\mu}{m_\tau}\right)^5 \frac{Br(\tau \to e\nu\bar{\nu})}{Br(\mu \to e\nu\bar{\nu})}$$

Sensitive to m_τ^5

- Beam energy measurement system is built to determine the energy precisely

BEPCII and BESIII



BEPCII

Energy region: 2.0 ~ 4.6GeV
Luminosity: 10^{33} $cm^{-2}s^{-1}$
1.89GeV
bunch: 2×93
current: 2×0.91A

BESIII

DC：position：135 μm，
momentum：0.5%@1GeV,
$\sigma_{dE/dx}$：6%

EMC：2.5%@1GeV
6 (9) mm

TOF：65 ps (B)
60 ps（EC）

μ counter：9 layers (B)
8 layers（EC）

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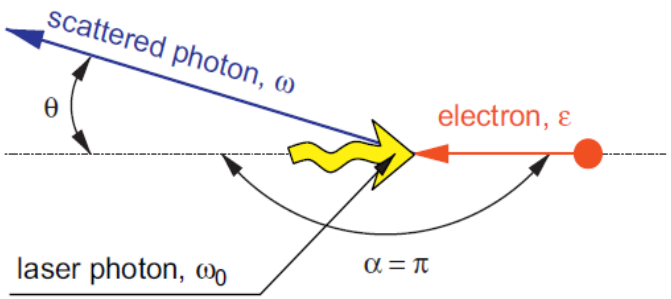
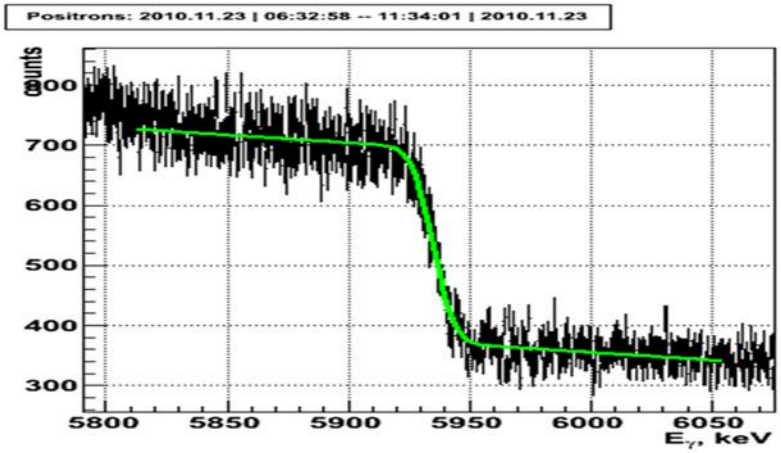
Beam energy measurement system (BEMS)





Energy of scattered photons:

$$\omega = \omega_0 \frac{1 - \beta \cos\alpha}{1 - \beta\cos\theta + \frac{\omega_0}{\varepsilon}(1 - \cos\Theta)}$$

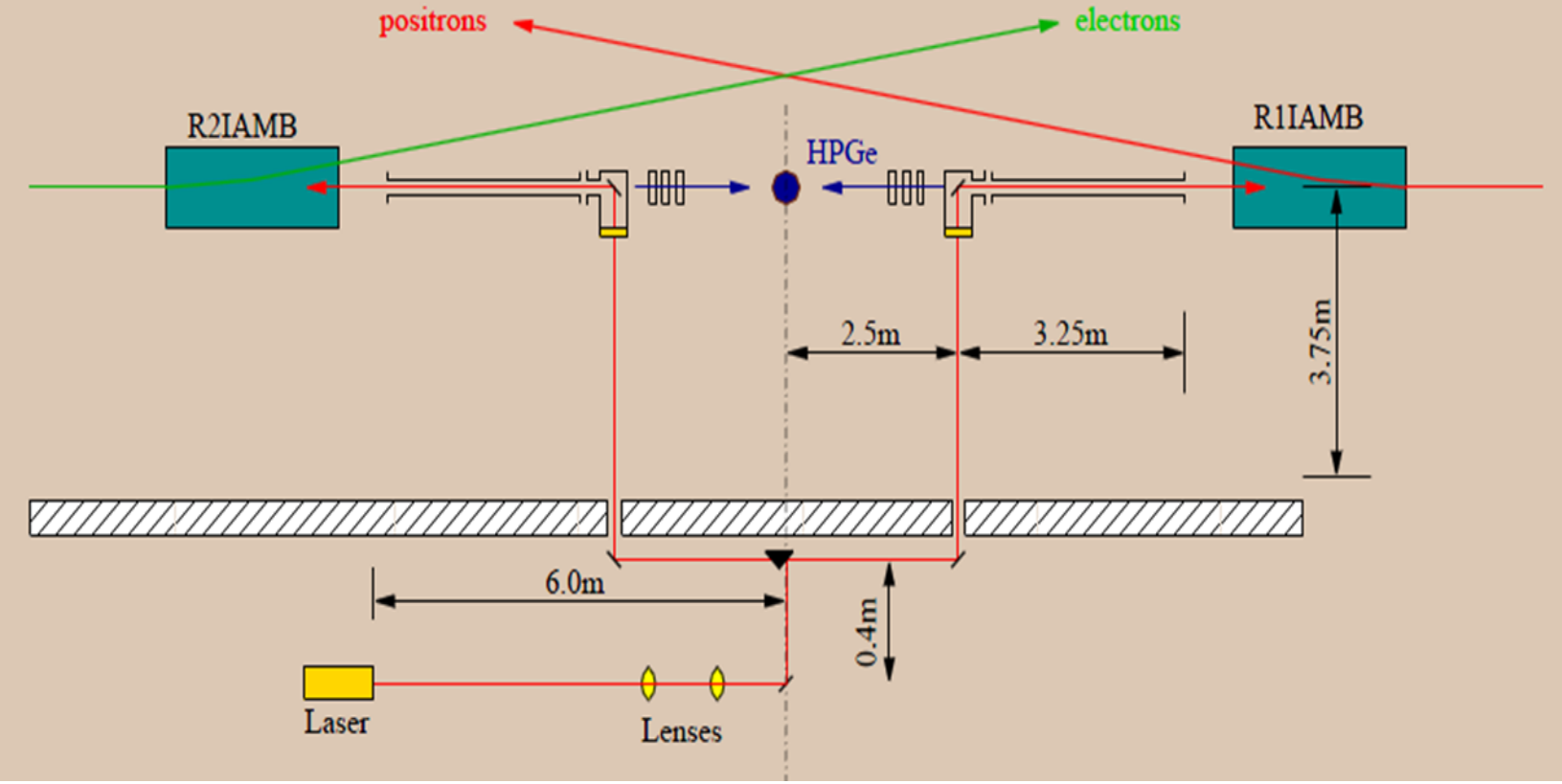
Head on collision, backscattered photons :

$$\omega_{max} = \frac{\varepsilon^2}{\varepsilon + m_e^2/4\omega_0^2},$$

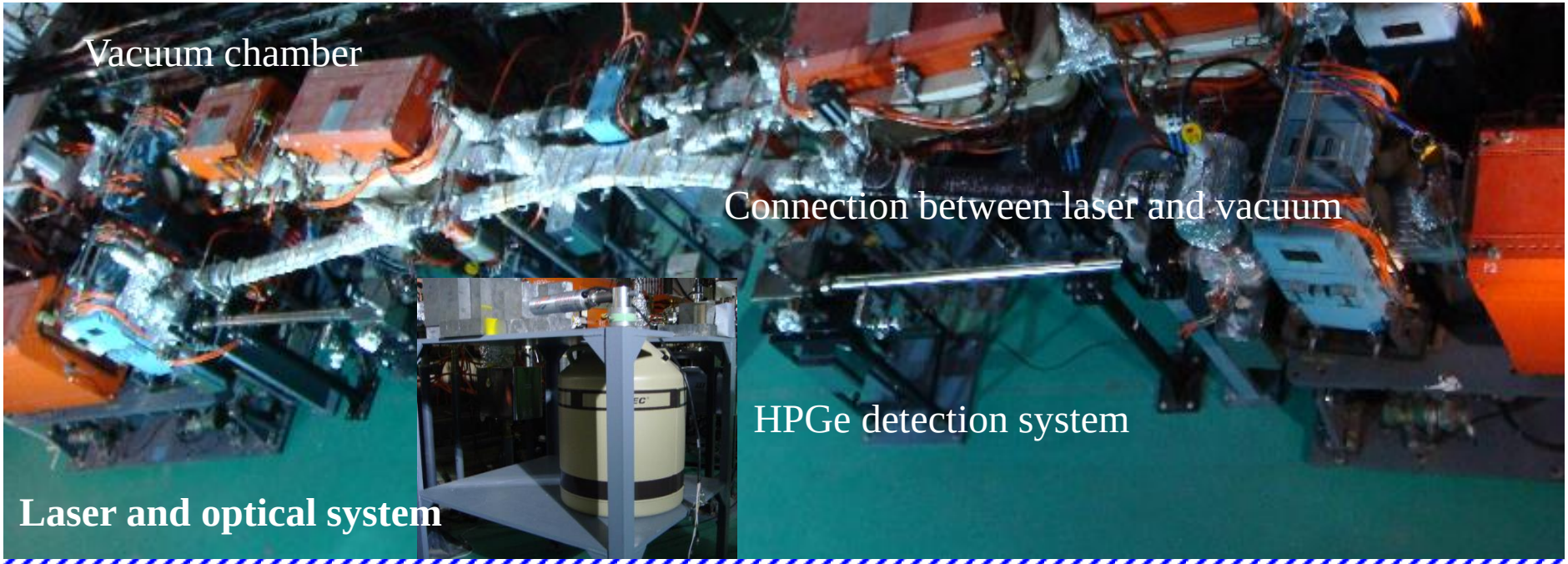
We get the beam energy:

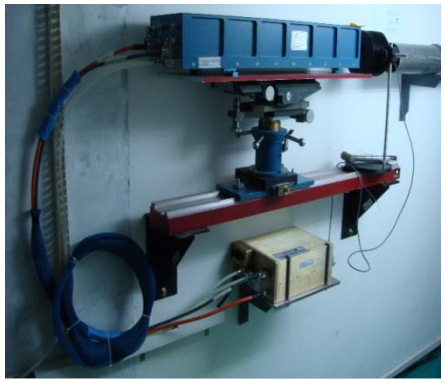
$$\varepsilon = \frac{\omega_{max}}{2}\left[1 + \sqrt{1 + \frac{m_e^2}{\omega_0\omega_{max}}}\right].$$

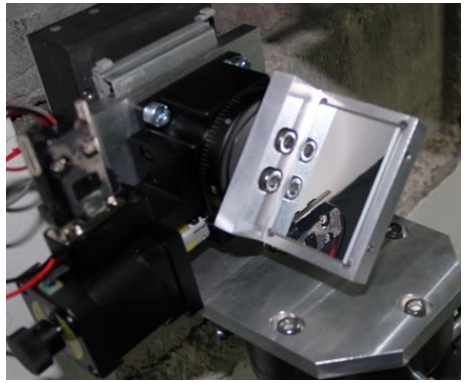
BEMS layout at BEPCII north crossing point

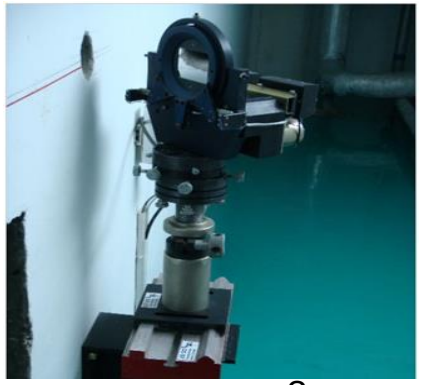


Installation of BEMS







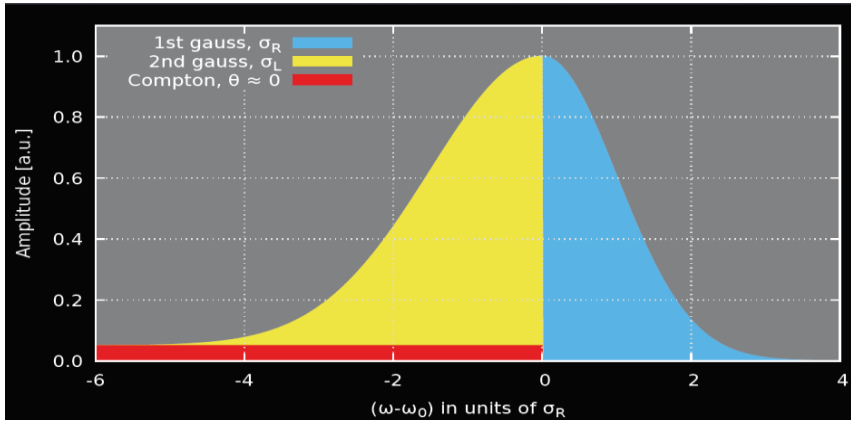


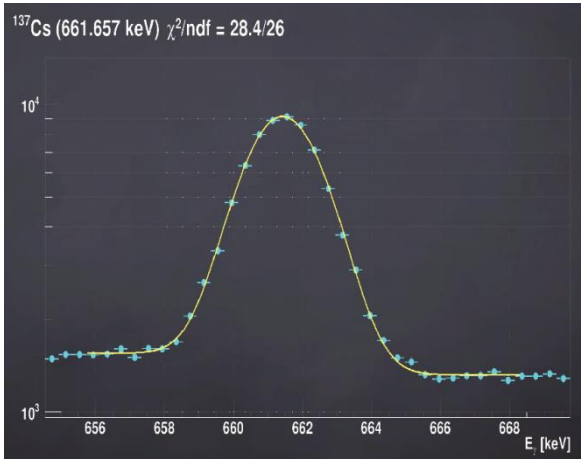
Detection system

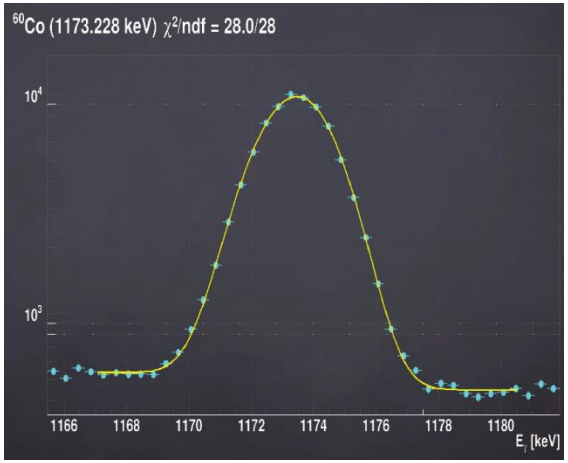
- Ortec n type coaxial HPGe detector
- Typical parameter of HPGe detector
  - Φ: 6 cm, height 6 cm
  - Energy resolution δω/ω: **10^{-3}**
  - relative efficiency: **30%**
- lead and paraffin are added to suppress neutrons and low energy photons
- The detector is connected to multichannel analyzer with Ortec DSpec Pro™ (integrated nonlinearity ±250 ppm)

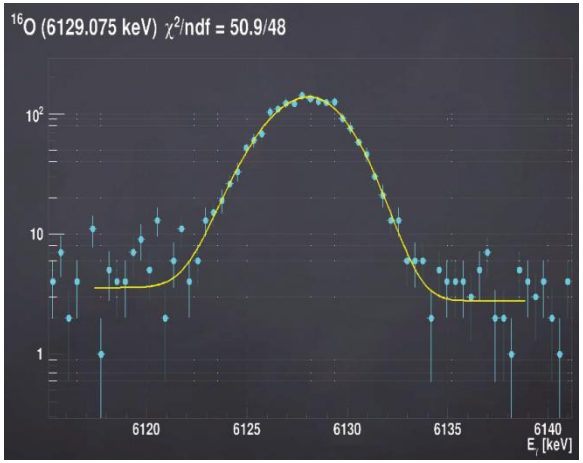
Detector calibration

Source	Decay half-time, years	γ-rays energies, keV
^{137}Cs	30.07	661.657 ± 0.003
^{60}Co	5.27	1173.228 ± 0.003 1332.492 ± 0.004
^{228}Th (^{208}Tl)	1.91 (3 min)	583.187 ± 0.002 2614.511 ± 0.010





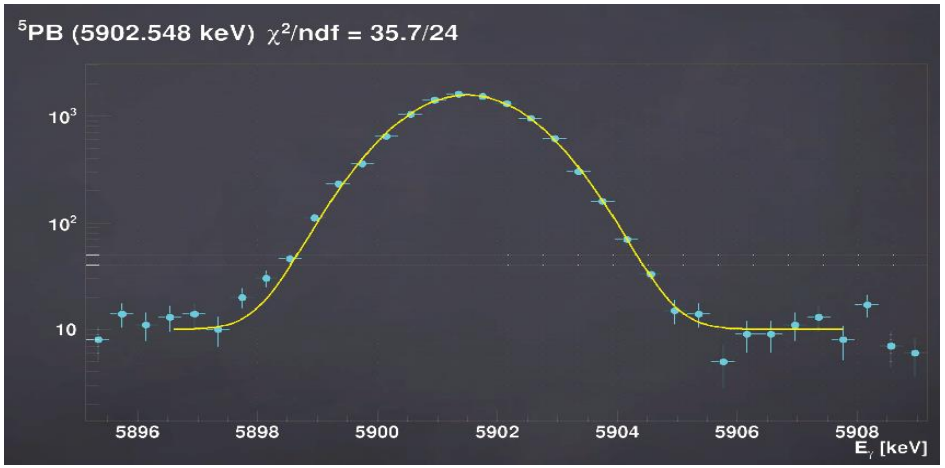




Detector calibration(II)

Interested energy are wide and radiation sources are limited

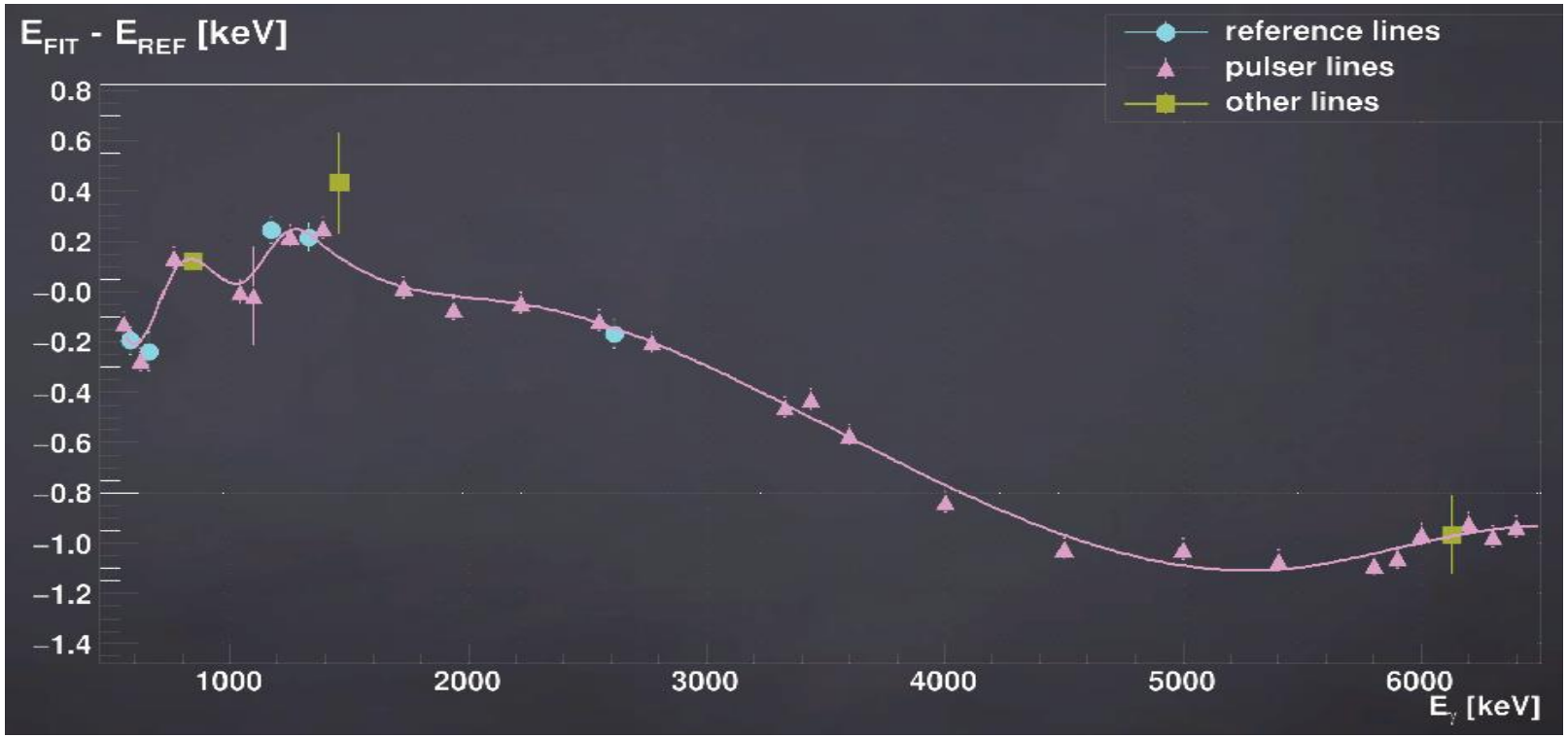
The nonlinearity of multichannel analyzer's scale is calibrated using the precise pulse generator (BNC-PB5) with integral nonlinearity **±15 ppm** jitter **±10 ppm**



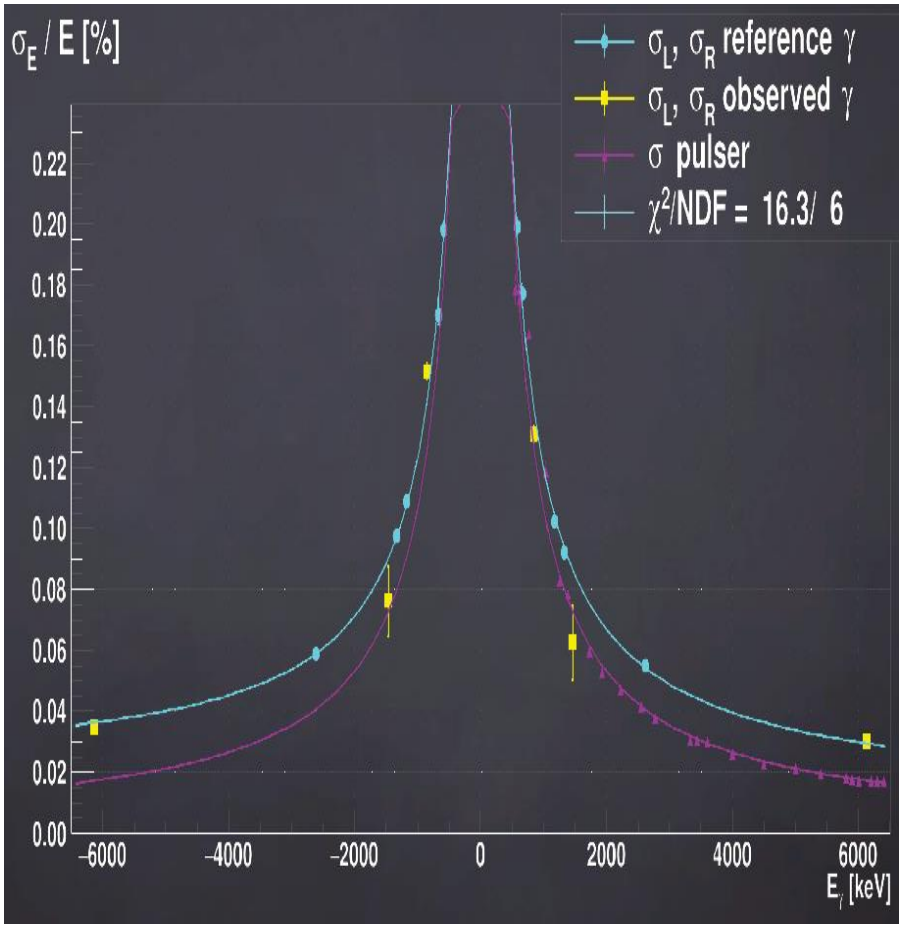
$$E_{ref,i}\ [\text{keV}] = P_0\ [\text{keV}] + P_1\ [\text{keV/V}] \cdot A_i\ [\text{V}]$$

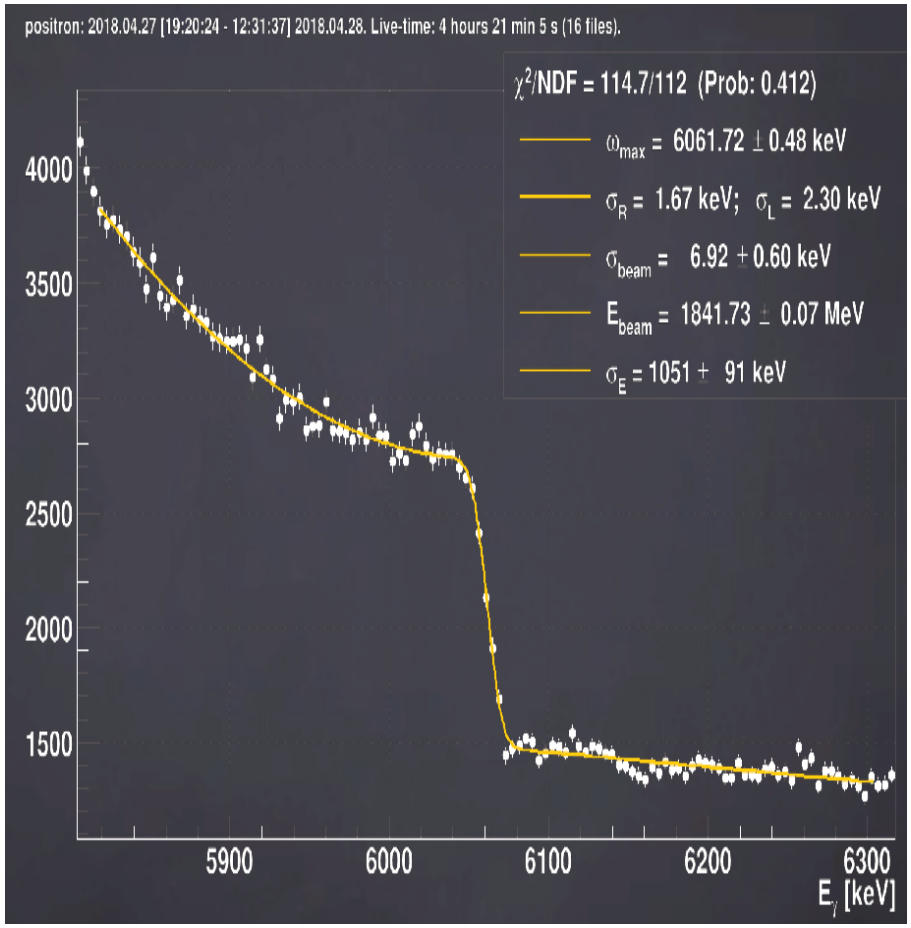
Detector calibration(III)

By tuning parameters p_0 and p_1 and comparing the reference lines and pulser lines :



Calibration and Compton edge fit





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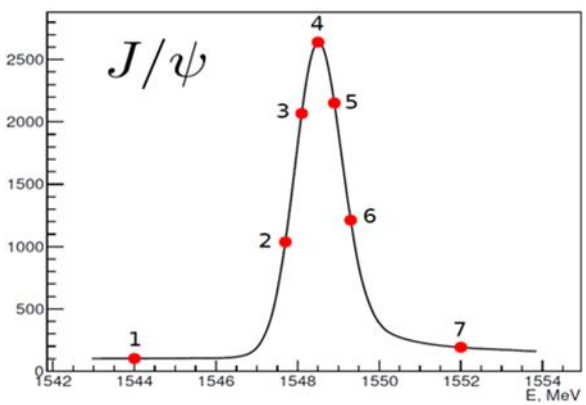
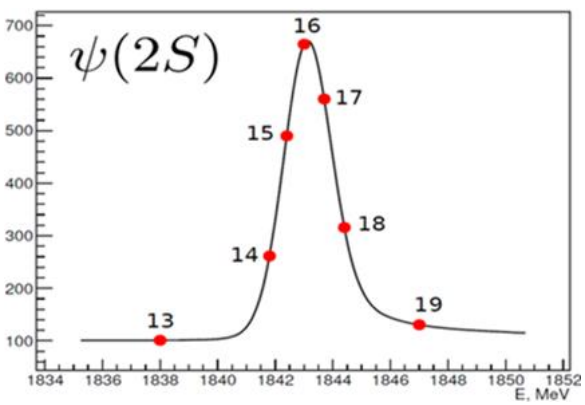
Data taking scenario

Three stages:

- J/Ψ scan for BEMS calibration and beam energy spread measurement (7 points)
- tau mass scan near tau threshold (5 points)
- Ψ' scan for BEMS calibration and beam energy spread measurement (7 points)



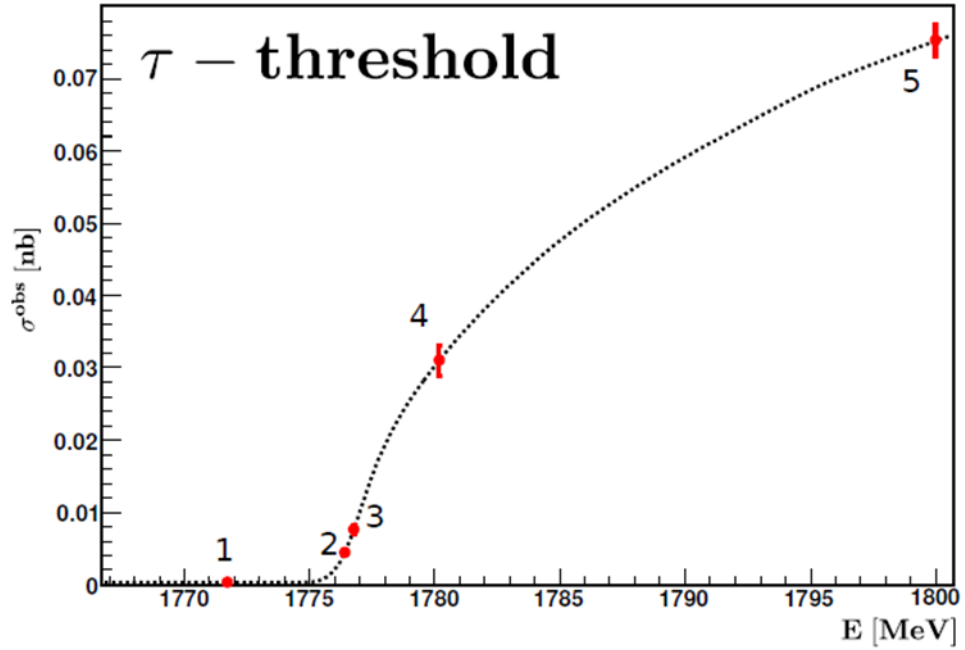


Data taking scenario (II)

Three energy regions:

- Low energy region
  Point 1, 14 pb^{-1}, to determine background
- Near threshold
  Point 2, 39 pb^{-1} and point 3, 26 pb^{-1}, to determine tau mass
- High energy region
  Point 4, 7 pb^{-1} for X^2 check
  Point 5, 14 pb^{-1} to determine detection efficiency

Total lum. ~100pb^{-1},
uncertainty: 0.1MeV



We obtain more than 130 pb^{-1} tau scan data!

Event selection

Two good charged tracks

$|v_z| < 10$ cm, $|v_{rxy}| < 1$ cm , $|\cos(\theta)| < 0.93$

$0.05 < p < 1.1$GeV

No good neutral tracks

eμ: Muons:

$E/p < 0.8$, $0.1<E<0.3$, MuC hit >0, Δtof (μ) < 0.35 ns

Electrons:

$0.8 < E/p < 1.1$, Δtof (e) < 0.35 ns

eπ: Pions:

Not μ, $E/p < 0.8$, $0.7<p<1.1$, Δtof (μ) < 0.35 ns

Tau mass fit

Tau mass is obtained using maximum likelihood fit

Free parameters are: $M\tau$, ε, σ_{bg}

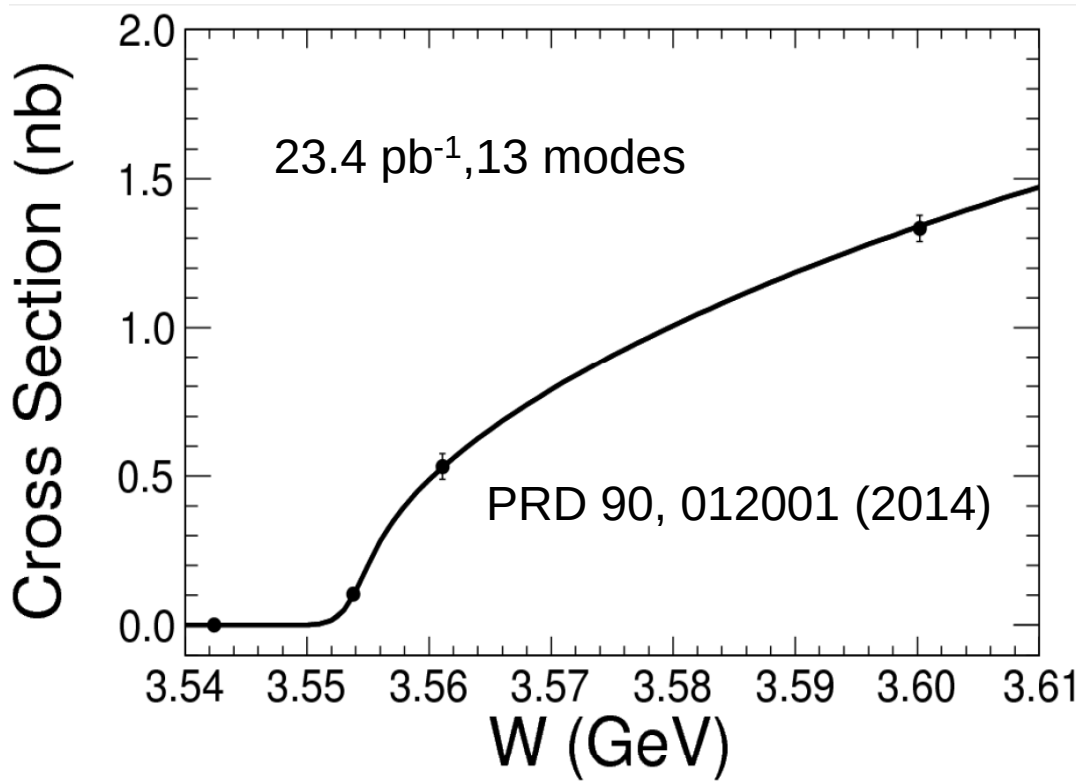
The statistic error of two modes ($e\mu$, $e\pi$) is about 70 keV

Systematic uncertainty is in progress

tau mass scan at BESIII in 2011

Systematic errors	
Source	keV
Theo.	10
E_{Spread}	16
E_{Scale}	+22 -86
$E_{Selection}$	50
Eff.	48
Bg. shape	40
Lum.	6
Sum	+100 -130

PDG2012: 1776.82 ±0.16 MeV



M_τ = 1776.91 ± 0.12 (stat.) $^{+0.10}_{-0.13}$ (sys.) MeV

δM_τ = 0.171 MeV, $\delta M_\tau / M_\tau = 9.6 \times 10^{-5}$

Data comparison

	J/ψ (pb-1)	ψ' (pb-1)	τ (pb-1)				
			3540 MeV	3553 MeV	3554 MeV	3560 MeV	3600 MeV
2011	1.5	7.5	4.3	0	5.6	3.9	9.6
2018	32.6	67.2	25.5	42.6	27.1	8.3	13.9

In 2011, two modes(eμ,eπ) , 454 events, extend 13 decay modes, We obtained 1171 events

$\sigma_{stat.}$ will be decrease to $\frac{0.070}{\sqrt{1171/454}}$ = 0.044 MeV

σ_{syst} is estimated to be 0.090 MeV if σ_{total} is required to be less than 0.1 MeV

Summary

Beam energy measurement system is commissioning well at BEPCII

Tau threshold scan was performed at BESIII this spring, more than 130 pb^{-1} data were collected

The further study on statistic and systematic uncertainty are in progress, the total uncertainty of tau mass is expected to be less than 0.1 MeV

Thank you for your concern!

tau mass scan @BESIII in 2011

In order to check the performance of the detector, the physical software and the BEMS, the τ scan was performed in the winter of 2011.

to resonances J/ψ and ψ' ,7 points are scanned, the integral luminosity are 1.5 pb^{-1}, 7.0 pb^{-1} separately

4 points near t threshold are scanned, 23.4 pb^{-1}

PRD 90, 012001 (2014)

Scan	E_{CM} (MeV)	$\mathcal{L}(nb^{-1})$
J/ψ	3088.7	78.5 ± 1.9
	3095.3	219.3 ± 3.1
	3096.7	243.1 ± 3.3
	3097.6	206.5 ± 3.1
	3098.3	223.5 ± 3.2
	3098.8	216.9 ± 3.1
	3103.9	317.3 ± 3.8
τ	3542.4	4252.1 ± 18.9
	3553.8	5566.7 ± 22.8
	3561.1	3889.2 ± 17.9
	3600.2	9553.0 ± 33.8
ψ'	3675.9	787.0 ± 7.2
	3683.7	823.1 ± 7.4
	3685.1	832.4 ± 7.5
	3686.3	1184.3 ± 9.1
	3687.6	1660.7 ± 11.0
	3688.8	767.7 ± 7.2
	3693.5	1470.8 ± 10.3

tau mass scan @BESIII in 2011

final state	1		2		3		4		total	
	Data	MC	Data	MC	Data	MC	Data	MC	Data	MC
ee	0	0	4	3.7	13	12.2	84	76.1	101	92.0
$e\mu$	0	0	8	9.1	35	31.4	168	192.6	211	233.1
$e\pi$	0	0	8	8.6	33	29.7	202	184.4	243	222.6
eK	0	0	0	0.5	2	1.8	16	16.9	18	19.3
$\mu\mu$	0	0	2	2.9	8	9.2	49	56.3	59	68.4
$\mu\pi$	0	0	4	3.9	11	14.1	89	86.7	104	104.7
μK	0	0	0	0.2	3	0.8	7	9.0	10	10.1
$\pi\pi$	0	0	1	2.0	5	7.7	57	54.0	63	63.8
πK	0	0	1	0.3	0	0.8	10	8.2	11	9.3
KK	0	0	0	0.0	1	0.1	1	0.3	2	0.4
$e\rho$	0	0	3	6.1	19	20.6	142	132.0	164	158.7
$\mu\rho$	0	0	8	3.3	18	11.8	52	63.3	68	78.5
$\pi\rho$	0	0	5	3.4	15	10.8	97	96.0	117	110.2
Total	0	0	44	44.2	153	151.2	974	975.7	1171	1171.0

PRD 90, 012001 (2014)