

Luminosity measurement for 2-3 GeV energy region

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For R-QCD group meeting

Outline

- Introduction
- Luminosity measurement with $e^+e^- \rightarrow e^+e^-$
- Check result with $e^+e^- \rightarrow \gamma\gamma$
- Systematic error analysis
- Summary

introduction

- Luminosity (integrated luminosity ,denoted as $\mathcal{L}$) is an important value of many measurement. So, precise measurement of luminosity is very necessary.
- In e^+e^- collider, the precise measurement is always achieved due to the well-understood QED processes $e^+e^- \rightarrow e^+e^-$, $e^+e^- \rightarrow \gamma\gamma$ and $e^+e^- \rightarrow \mu^+\mu^-$
- For a specific physical process, the corresponding luminosity is determined as

$$\mathcal{L} = \frac{N}{\sigma * \epsilon}$$

where N is the number of event, σ is cross section of the physical process and ϵ denotes the detection efficiency.

Data & MC version

- Data : taken from Dec 30 2014 to May 30 2015
- MC version: BOSS664p01
- MC sample: Ecm (2.000GeV ~3.08 GeV 21 energy points)

500000 $e^+e^- \rightarrow \gamma\gamma$ (babayaga)

500000 $e^+e^- \rightarrow e^+e^-$ (babayaga)

300000 $e^+e^- \rightarrow \mu^+\mu^-$ (babayaga)

300000 $e^+e^- \rightarrow \text{hadrons}$ (lundarlw+exclusive)

300000 $e^+e^- \rightarrow e^+ e^- X$ (two photon process)

Data sample

Ecm(GeV)	runNo. range	Numberof run	date	notes
2.0000	41729-41909	163	150418-150427	
2.0500	41911-41957	46	150427-150430	
2.1000	41588-41727	126	150411-150418	
2.1500	41533-41570	35	150409-150411	
2.1750	41416-41532	113	150403-150409	
2.2000	40989-41121	121	150312-150320	
2.2324	41122-41239	113	150320-150326	
2.3094	41240-41411	162	150326-150402	
2.3864	40806-40951	94	150303-150311	
2.3960	40459-40769	273	150214-150228	
2.5000	40771-40776	6	150228	
2.6444	40128-40296	146	150131-150207	
2.6464	40300-40435	112	150207-150213	
2.7000	40436-40439	4	150213	
2.8000	40440-40443	4	150213	
2.9000	39775-40069	280	150116-150130	
2.9500	39619-39650	32	150111-150112	
2.9810	39651-39679	27	150112-150113	
3.0000	39680-39710	24	150113-150114	
3.0200	39711-39738	25	150114-150116	
3.0800	39355-39618	217	141231-150111	
2.2324	41959-41999	41	150430	Sep. beam data
2.6444	40777-40804	28	150302	Sep. beam data

luminosity measurement

$$e^+e^- \rightarrow e^+e^-$$

Event selection

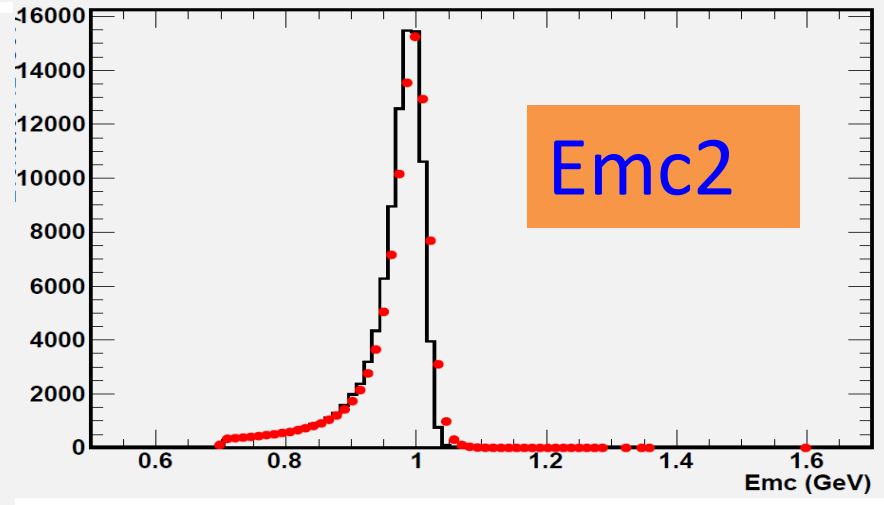
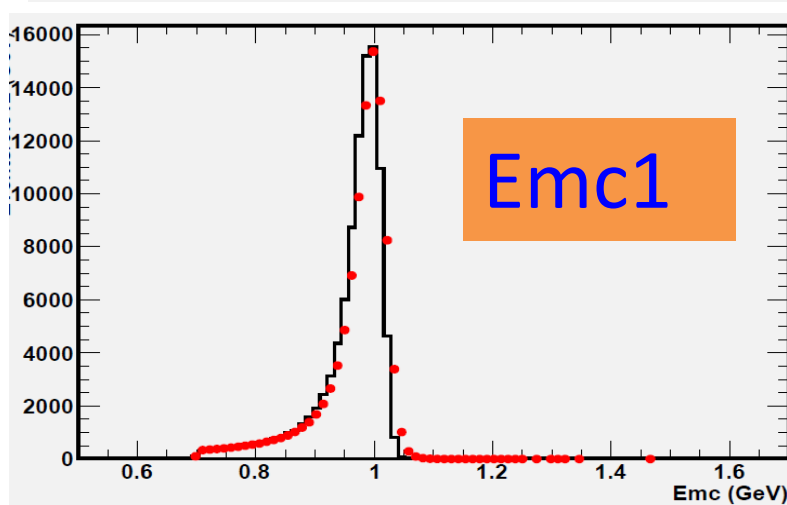
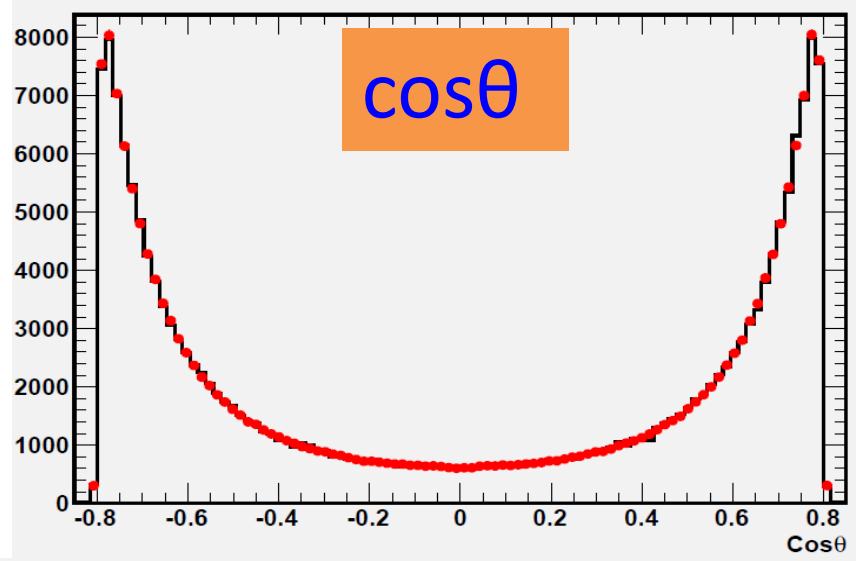
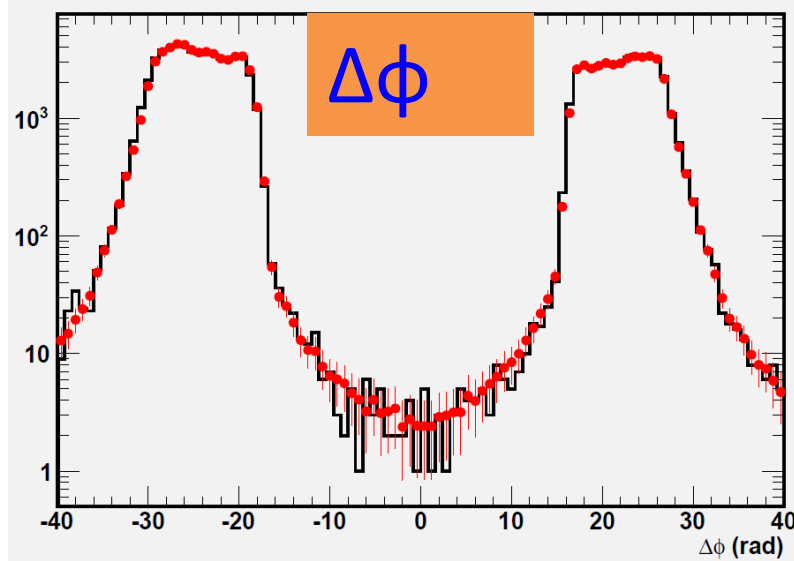
- Select out the two good charged tracks ($N_{\text{good}} \geq 2$)
 - a) $V_r < 1\text{cm}$, $|V_z| < 10\text{cm}$
 - b) Momentum of each track less than 2.0GeV
- Deposited energy of each charged track in EMC great than $0.35E_{\text{beam}}$ GeV
- Absolute cosine theta of each charged track less than 0.8

Background estimation(2.000GeV)

Item	$e^+e^- \rightarrow \gamma\gamma$	$e^+e^- \rightarrow \mu^+\mu^-$	$e^+e^- \rightarrow e^+e^-X$	$e^+e^- \rightarrow \text{hadrons}$
ϵ^b	1.2e-5	0.	3.3e-4	2.1e-4
σ^b	87.4	22.4	1.5	12.3
N_b	1	0	5	26

The ratio of background to signal events
is 8.9e-6

Some distribution comparison



Luminosity calculation

$$\mathcal{L} = \frac{N_s}{(\sigma^s * \epsilon^s + \sigma^{uu} * \epsilon^{uu} + \sigma^{\gamma\gamma} * \epsilon^{\gamma\gamma} + \sigma^{eeX} * \epsilon^{eeX} + \sigma^{had} * \epsilon^{had})}$$

$$\mathcal{L}^{2.0000} = 10.063 \pm 0.005 (pb^{-1})$$

$$N_s = 3609518$$

$$\sigma^s = 1838.07 \pm 3.45 \text{ (nb)}$$

$$\epsilon^s = 0.1952 \pm 0.0006$$

Integrated luminosity for all energy points (I)

$E_{\text{cm}}(\text{GeV})$	σ (nb)	ϵ	$N_{\text{sig}}/N_{\text{bkg}}$	$\mathcal{L}$ (pb^{-1})	notes
2.0000	1838.07	0.1952	3609518/16	10.063 ± 0.005	
2.0500	1754.30	0.1935	1137413/7	3.351 ± 0.003	
2.1000	1666.92	0.1948	3939113/25	12.129 ± 0.006	
2.1500	1594.26	0.1938	878445/4	2.843 ± 0.003	
2.1750	1555.38	0.1946	3215240/26	10.622 ± 0.006	
2.2000	1519.45	0.1941	4032894/32	13.672 ± 0.007	
2.2324	1476.54	0.1930	3401798/17	11.937 ± 0.006	
2.3094	1385.12	0.1939	5639366/30	21.001 ± 0.009	
2.3864	1291.41	0.1935	5669996/24	22.692 ± 0.010	
2.3960	1281.10	0.1936	16630381/68	67.070 ± 0.016	
2.5000	1179.92	0.1936	251419/2	1.101 ± 0.002	

Integrated luminosity for all energy points(II)

$E_{\text{cm}}(\text{GeV})$	σ (nb)	ϵ	$N_{\text{sig}}/N_{\text{bkg}}$	$\mathcal{L}$ (pb^{-1})	Notes
2.6444	1056.45	0.1941	6885993/29	33.603 ± 0.013	
2.6464	1052.52	0.1934	6976585/43	34.274 ± 0.013	
2.7000	1013.35	0.1940	203230/2	1.034 ± 0.002	
2.8000	941.86	0.1945	183937/2	1.004 ± 0.002	
2.9000	877.53	0.1945	18026415/146	105.618 ± 0.025	
2.9500	847.79	0.1940	2639622/20	16.046 ± 0.010	
2.9810	829.06	0.1947	2596593/15	16.089 ± 0.010	
3.0000	823.19	0.1946	2532847/16	15.809 ± 0.010	
3.0200	808.06	0.1940	2728340/18	17.404 ± 0.011	
3.0800	777.58	0.1952	18213861/122	119.985 ± 0.028	

Luminosity measurement check with $e^+e^- \rightarrow \gamma \gamma$

Event selection

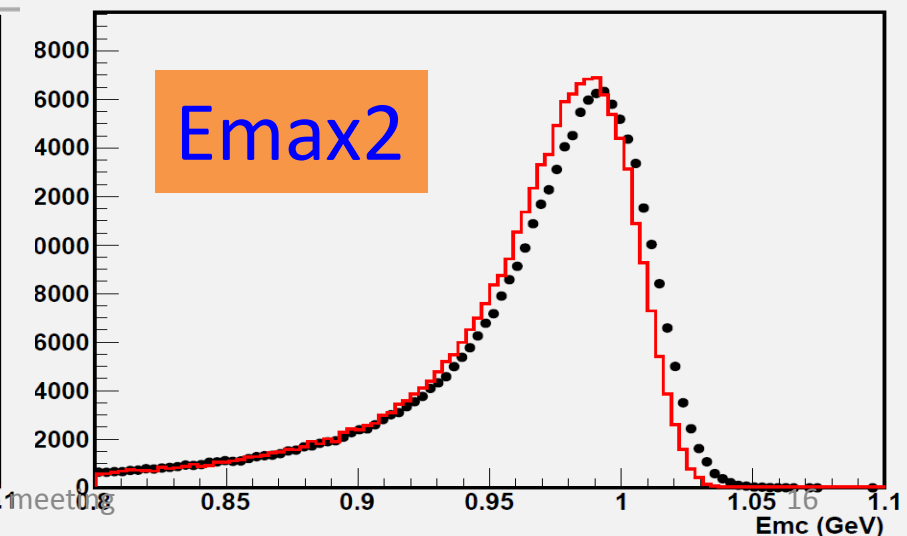
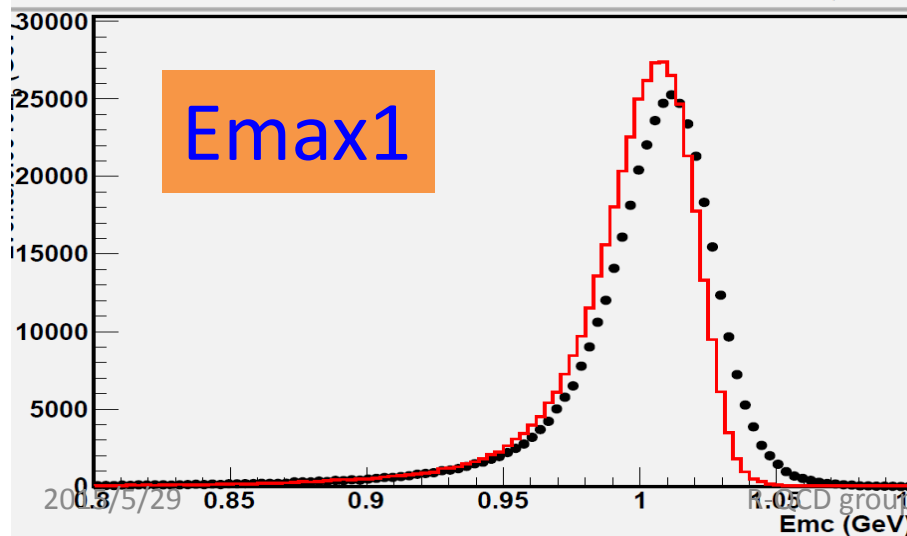
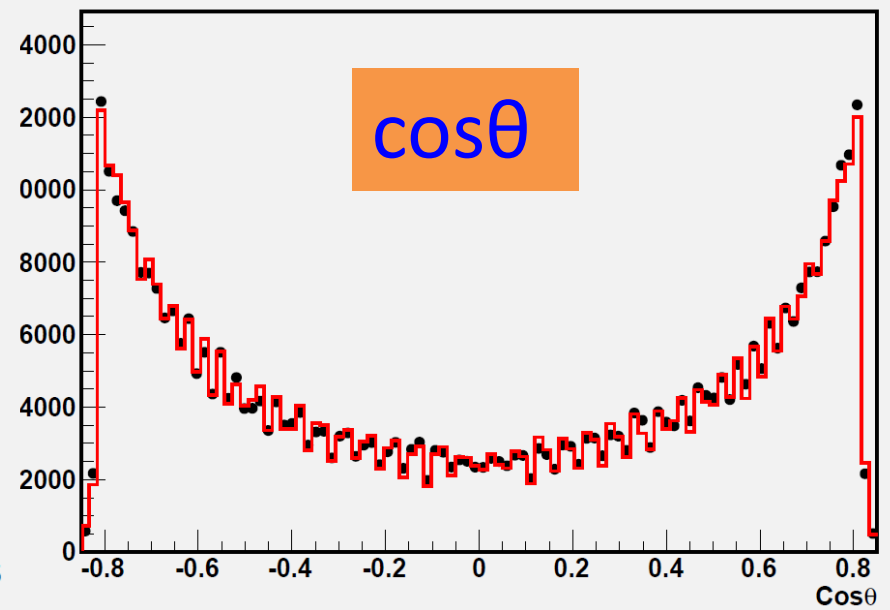
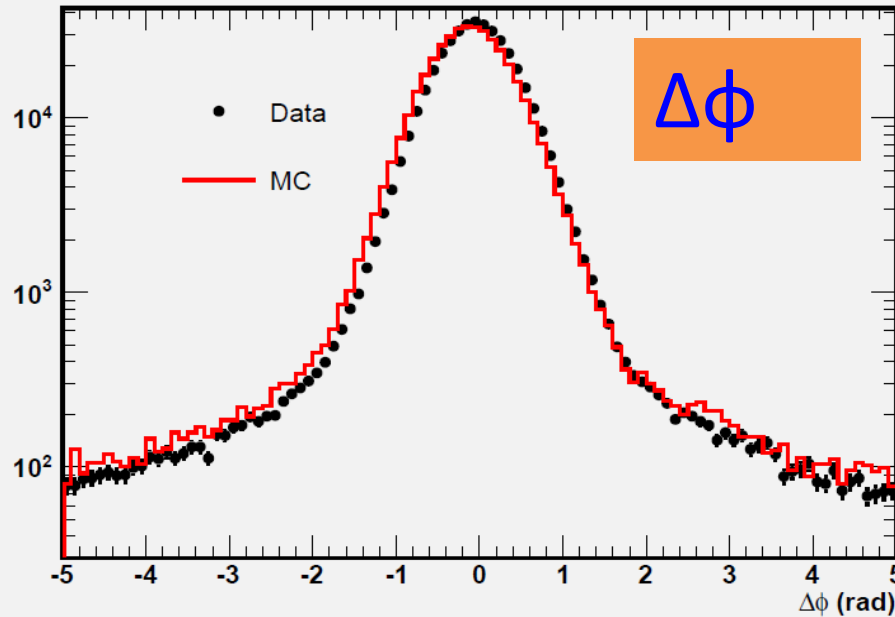
- Select out the two photons of maximum deposited energy
- Deposited energy of first maximum photon less than 2.0GeV
- Deposited energy of second maximum photon great than 0.35Ebeam ,and less than 0.58 Ebeam GeV energy points.
- $|\cos\theta| < 0.8$
- The number of charged track is zero
- $|\Delta\phi| < 2.5$ (degree) $\Delta\phi = |\phi_1 - \phi_2| - 180^\circ$
 ϕ is the azimuthal angle in EMC

Background estimation(2.000GeV)

Item	$e^+e^- \rightarrow e^+e^-$	$e^+e^- \rightarrow \mu^+\mu^-$	$e^+e^- \rightarrow e^+e^-X$	$e^+e^- \rightarrow \text{hadrons}$
ϵ^b	2.0e-6	0.000	0.000	2.0e-4
σ^b	1838.1	22.4	1.5	12.3
N_b	37	0	0	25

The ratio of background to signal events is 1.5e-4

Some distribution comparison



Luminosity calculation

$$\mathcal{L} = \frac{N_s - N_{sid}}{\sigma^s * \epsilon^s}$$

$$\mathcal{L}^{2.0000} = 10.156 \pm 0.016 (pb^{-1})$$

where : $N_s = 416779$ $N_{sid} = 5873$

$\sigma^s = 87.36 \pm 0.09$ (nb)

$\epsilon^s = 0.4631 \pm 0.0007$

Integrated luminosity for all energy points (I)

$E_{cm}(\text{GeV})$	σ (nb)	ϵ	Nsig/Nsid	$\mathcal{L}$ (pb ⁻¹)	notes
2.0000	87.36	0.4631	416779/5873	10.156 ± 0.016	
2.0500	83.17	0.4635	131205/1787	3.3570 ± 0.009	
2.1000	79.32	0.4626	452298/6106	12.160 ± 0.018	
2.1500	75.67	0.4634	101404/1366	2.8530 ± 0.009	
2.1750	73.96	0.4624	370875/5086	10.695 ± 0.018	
2.2000	72.34	0.4636	463259/6129	13.632 ± 0.020	
2.2324	70.26	0.4628	390775/5460	11.850 ± 0.019	
2.3094	65.67	0.4620	647624/8735	21.057 ± 0.026	
2.3864	61.54	0.4626	651442/8752	22.577 ± 0.028	
2.3960	61.06	0.4640	1907725/25359	66.437 ± 0.048	
2.5000	56.10	0.4634	28859/369	1.096 ± 0.006	

Integrated luminosity for all energy points(II)

$E_{\text{cm}}(\text{GeV})$	σ (nb)	ϵ	$N_{\text{sig}}/N_{\text{sid}}$	$\mathcal{L}$ (pb^{-1})	Notes
2.6444	50.19	0.4620	787596/10386	33.547 ± 0.038	
2.6464	50.12	0.4618	797551/10504	34.005 ± 0.038	
2.7000	48.17	0.4644	22977/315	1.013 ± 0.007	
2.8000	44.81	0.4621	20965/254	1.000 ± 0.007	
2.9000	41.77	0.4608	2056477/26880	105.455 ± 0.074	
2.9500	40.34	0.4614	300457/3896	15.932 ± 0.029	
2.9810	39.52	0.4632	295867/3805	15.958 ± 0.030	
3.0000	39.02	0.4620	287812/3653	15.763 ± 0.030	
3.0200	38.51	0.4617	310217/4174	17.214 ± 0.030	
3.0800	37.02	0.4622	2065011/26947	119.085 ± 0.083	

Comparison between different processes

E_{cm} (GeV)	$e^+e^- \rightarrow e^+e^-$	$e^+e^- \rightarrow \gamma\gamma$	δ (%)
2.000	10.063	10.156	0.9
2.050	3.351	3.357	0.2
2.100	12.129	12.160	0.3
2.150	2.843	2.853	0.4
2.175	10.622	10.695	0.7
2.200	13.672	13.632	0.3
2.232	11.937	11.850	0.7
2.309	21.001	21.057	0.3
2.386	22.692	22.577	0.5
2.396	67.070	66.437	0.9
2.500	1.101	1.096	0.5
2.644	33.575	33.518	0.2
2.646	34.274	34.005	0.8
2.700	1.034	1.013	2.0
2.800	1.004	1.000	0.4
2.900	105.618	105.455	0.2
2.950	16.046	15.932	0.7
2.981	16.089	15.958	0.8
3.000	15.809	15.763	0.3
3.020	17.404	17.214	1.1
3.080	119.985	119.085	0.8

Summary

- ① Integrated Luminosity for 2-3 GeV energy region (data taken from Dec. 30 2014 to May 30 2015) have been measured under BOSS 664p01 version (see Results page 20 in detail)
- ② Next step systematic error will be analyzed for all the energy points.

Thank your attention !