

Luminosity measurement for the new R-QCD data

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For the 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 April 30 2015
- MC version: BOSS665p01
- MC sample: E_{cm} (2.000GeV $\sim$ 3.080 GeV 21 energy points)
 - 1000000 $e^+e^- \rightarrow \gamma\gamma$ (babayaga)
 - 1000000 $e^+e^- \rightarrow e^+e^-$ (babayaga)
 - 500000 $e^+e^- \rightarrow \mu^+\mu^-$ (babayaga)
 - 500000 $e^+e^- \rightarrow \text{hadrons}$ (lundarlw+exclusive)
 - 500000 $e^+e^- \rightarrow e^+ e^- X$ (two photon process)

Data sample

Ecm(GeV)	runNo. range	Numberof run	date	notes
2.0000	41729-41909	159	150418-150427	
2.0500	41911-41957	46	150427-150429	
2.1000	41588-41728	127	150411-150418	
2.1500	41533-41570	35	150409-150411	
2.1750	41416-41532	111	150403-150409	
2.2000	40989-41121	121	150312-150319	
2.2324	41123-41239	113	150320-150325	
2.3094	41240-41411	161	150326-150402	
2.3864	40806-40951	94	150302-150307	
2.3960	40463-40769	269	150214-150228	
2.5000	40771-40776	6	150228	
2.6444	40128-40298	146	150131-150207	
2.6464	40300-40435	123	150207-150212	
2.7000	40436-40439	4	150213	
2.8000	40440-40443	4	150213	
2.9000	39775-40069	280	150116-150129	
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	150114-150115	
3.0800	39355-39618	225	141231-150110	
2.2324	41959-41999	41	150430	Sep. beam data
2.6444	40777-40804	28	150228-150302	Sep. beam data

Common code address

**/ihepbatch/bes/zhangbx/workarea-
665p01/RscanDQ/RscanDQ-00-00-01**

Data sets address

/bes3fs/offline/data/665p01/rscan/dst/

luminosity measurement

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

Event selection

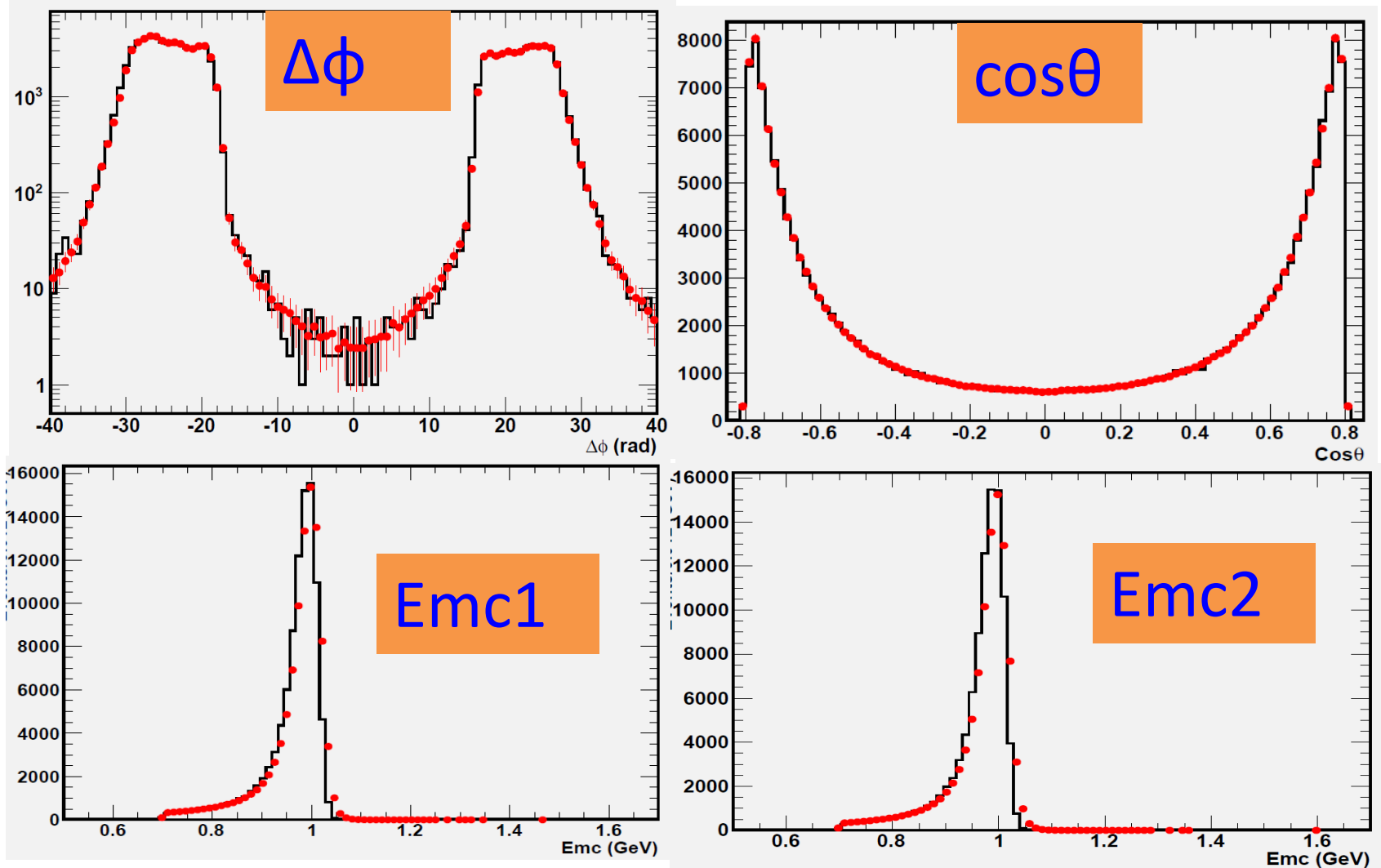
- Select out the two good charged tracks, their deposited energy is energetic.
 - a) $V_r < 1\text{cm}$, $|V_z| < 10\text{cm}$
 - b) Momentum of each track less than 2.0GeV
 - Deposited energy of each charged track in EMC great than $0.35E_{\text{cm}}$ GeV
 - Absolute cosine theta of each charged track less than 0.8
 - $|\Delta\theta| < 10^\circ$ $\Delta\theta = |\theta_1 + \theta_2| - 1800$
 - $5^\circ < |\Delta\Phi| < 40^\circ$ $\Delta\Phi = |\phi_1 - \phi_2| - 1800$
- back to back cuts**

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	6.0e-5	6.0e-6	2.2e-4	4.0e-5
σ^b	87.0	22.4	1.5	56.0
N_b	6	2	4	23

The ratio of background to signal events is 1.0e-5 (Lum=10.079pb⁻¹)

Some distribution comparison



Luminosity calculation

$$\mathcal{L} = \frac{N_{obs} - N_{bkg}}{\sigma * \epsilon}$$

$$\mathcal{L} = 10.074 \pm 0.005 \text{ (pb}^{-1}\text{)}$$

$$N_{obs} = 3485634 \quad N_{bkg} = 35$$

$$\sigma^s = 1837.91 \pm 1.37 \text{ (nb)}$$

$$\epsilon^s = 0.1882 \pm 0.0004$$

Integrated luminosity for all energy points (I)

$E_{cm}(\text{GeV})$	σ (nb)	ϵ	N_{sig}/N_{bkg}	$\mathcal{L}$ (pb ⁻¹) offline	$\mathcal{L}$ (pb ⁻¹) online	Difference(%)
2.0000	1837.91	0.1882	3485215/33	10.074 ± 0.005	9.306	7.6
2.0500	1749.86	0.1878	1098564/11	3.343 ± 0.003	3.018	9.7
2.1000	1667.85	0.1874	3803220/32	12.167 ± 0.006	11.348	6.7
2.1500	1591.59	0.1876	848218/7	2.841 ± 0.003	2.755	3.0
2.1750	1555.42	0.1878	3103173/35	10.625 ± 0.006	10.056	5.4
2.2000	1520.44	0.1869	3892106/69	13.699 ± 0.007	13.005	5.1
2.2324	1476.92	0.1875	3283207/23	11.856 ± 0.007	11.248	5.1
2.3094	1380.70	0.1867	5436694/44	21.089 ± 0.009	20.482	2.9
2.3864	1293.39	0.1875	5468583/50	22.549 ± 0.010	22.059	2.2
2.3960	1283.05	0.1869	16038444/237	66.869 ± 0.017	64.841	3.0
2.5000	1179.05	0.1873	242405/3	1.098 ± 0.002	1.044	4.9

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) offline	$\mathcal{L}$ (pb ⁻¹) online	Difference(%)
2.6444	1054.32	0.1873	6657891/65	33.722 ± 0.013	32.530	3.5
2.6464	1052.78	0.1878	6723099/45	34.003 ± 0.013	33.730	0.8
2.7000	1011.63	0.1873	195864/3	1.034 ± 0.002	0.987	4.5
2.8000	941.11	0.1868	177225/2	1.008 ± 0.002	0.965	4.3
2.9000	877.68	0.1879	17354191/271	105.253 ± 0.025	102.096	3.0
2.9500	848.32	0.1878	2540009/31	15.942 ± 0.010	15.696	1.5
2.9810	830.87	0.1871	2498816/64	16.071 ± 0.010	15.391	4.2
3.0000	820.40	0.1870	2436871/41	15.881 ± 0.010	15.269	3.9
3.0200	809.55	0.1875	2624422/48	17.290 ± 0.011	16.605	4.0
3.0800	778.47	0.1869	18357589/354	126.185 ± 0.029	123.025	2.5

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

Event selection

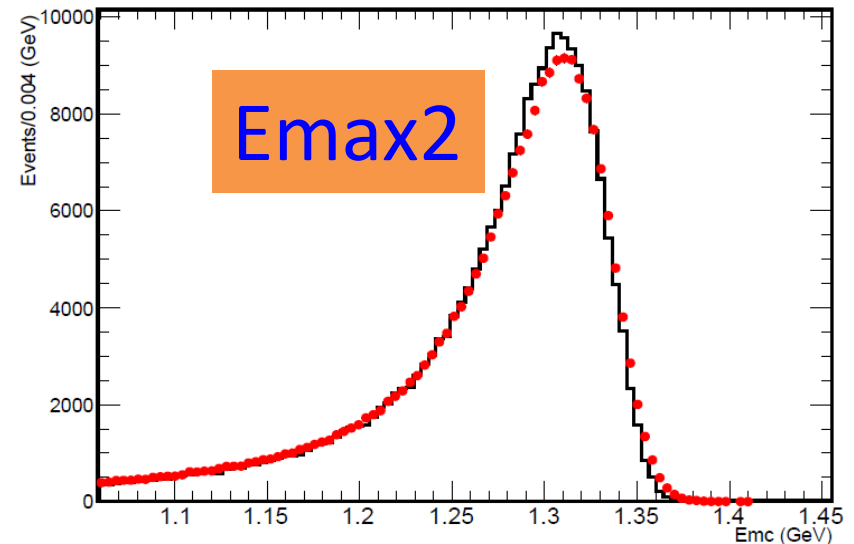
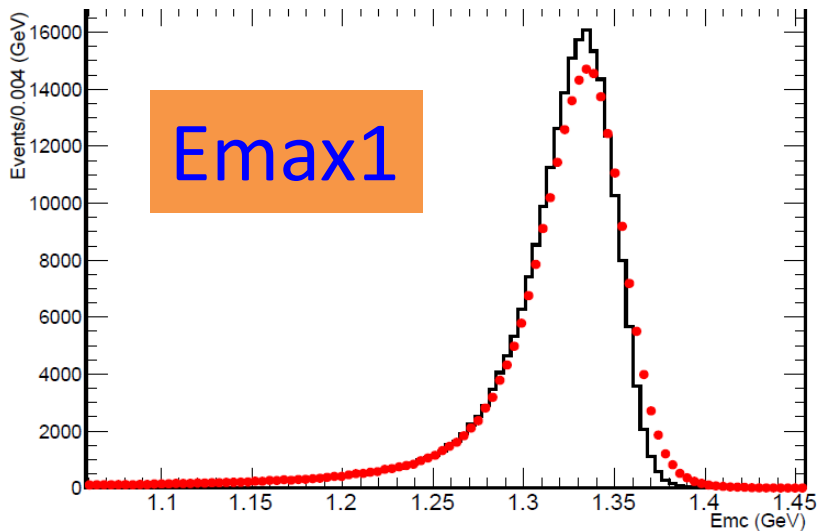
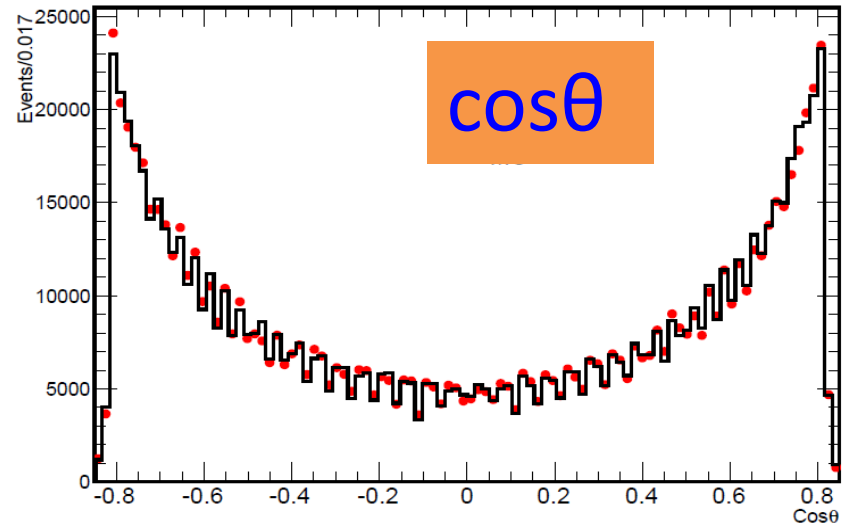
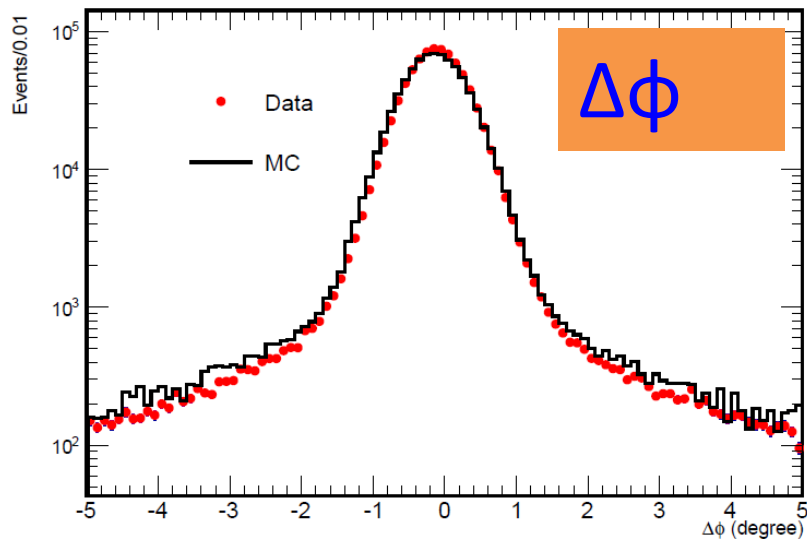
- Select out the two photons of maximum deposited energy
- Deposited energy of first maximum photon less than 2.0GeV
- Deposited energy of second maximum photon great than 0.35Ecm ,and less than 0.58Ecm GeV energy points.
- $|\cos\theta| < 0.8$
- The number of charged track is zero
- $|\Delta\phi| < 2.5$ (degree) $\Delta\phi = |\phi_1 - \phi_2| - 180^\circ$
 ϕ is the azimuthal angle in EMC .
2.5 < $|\Delta\phi|$ < 5 (sideband region)

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	1.6e-5	0.000	0.000	2.2e-5
σ^b	1839.4	22.4	1.5	56.0
N_b	297	0	0	13

The ratio of background to signal events is $7.5e-4$ (Lum=10.079pb⁻¹)

Some distribution comparison



Luminosity calculation

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

$$\mathcal{L}^{2.0000} = 10.079 \pm 0.016 (pb^{-1})$$

where : $N_{sig} = 416733$ $N_{sid} = 5871$

$$\sigma^s = 87.69 \pm 0.09 \text{ (nb)}$$

$$\epsilon^s = 0.4649 \pm 0.0007$$

Integrated luminosity for all energy points (I)

$E_{cm}(\text{GeV})$	σ (nb)	ϵ	Nsig/Nsid	$\mathcal{L}$ (pb ⁻¹)	notes
2.0000	87.69	0.4649	416733/5871	10.079 ± 0.016	
2.0500	83.48	0.4645	131217/1791	3.337 ± 0.009	
2.1000	79.56	0.4649	453220/6120	12.089 ± 0.018	
2.1500	75.91	0.4638	101407/1370	2.841 ± 0.009	
2.1750	74.18	0.4647	370837/5093	10.609 ± 0.018	
2.2000	72.51	0.4649	463284/6136	13.561 ± 0.020	
2.2324	70.43	0.4642	390783/5466	11.786 ± 0.019	
2.3094	65.81	0.4639	647020/8744	20.907 ± 0.026	
2.3864	61.65	0.4630	651506/8748	22.520 ± 0.028	
2.3960	61.15	0.4640	1907603/25401	66.326 ± 0.048	
2.5000	56.18	0.4637	28852/364	1.093 ± 0.006	

Integrated luminosity for all energy points(II)

$E_{cm}(\text{GeV})$	σ (nb)	ϵ	N_{sig}/N_{sid}	$\mathcal{L}$ (pb^{-1})	Notes
2.6444	50.23	0.4624	790243/10413	33.573 ± 0.038	
2.6464	50.15	0.4640	797571/10521	33.818 ± 0.038	
2.7000	48.19	0.4625	22979/317	1.017 ± 0.007	
2.8000	44.82	0.4625	20968/251	0.999 ± 0.007	
2.9000	41.80	0.4633	2057046/26966	104.841 ± 0.074	
2.9500	40.39	0.4616	300499/3904	15.909 ± 0.029	
2.9810	39.56	0.4640	295844/3809	15.908 ± 0.030	
3.0000	39.07	0.4632	287861/3657	15.708 ± 0.030	
3.0200	38.55	0.4615	310240/4189	17.201 ± 0.030	
3.0800	37.07	0.4618	2164038/28300	124.770 ± 0.085	

Comparison between different processes

E_{cm} (GeV)	$e^+e^- \rightarrow e^+e^-$	$e^+e^- \rightarrow \gamma\gamma$	δ (%)
2.0000	10.074	10.079	~ 0.0
2.0500	3.343	3.337	0.2
2.1000	12.167	12.089	0.6
2.1500	2.841	2.841	~ 0.0
2.1750	10.625	10.609	0.2
2.2000	13.699	13.561	1.0
2.2324	11.856	11.786	0.6
2.3094	21.089	20.907	0.9
2.3864	22.549	22.520	0.1
2.3960	66.869	66.326	0.8
2.5000	1.098	1.093	0.5
2.6444	33.722	33.573	0.4
2.6464	34.003	33.818	0.5
2.7000	1.034	1.017	1.6
2.8000	1.008	0.999	0.9
2.9000	105.253	104.841	0.4
2.9500	15.942	15.909	0.2
2.9810	16.071	15.908	1.0
3.0000	15.881	15.708	1.1
3.0200	17.290	17.201	0.5
3.0800	126.185	124.770	1.1

Systematic error analysis

- Track efficiency with two different analysis methods to determined the Luminosity (see memo BAM-00157 in detail)
- Systematic error from generator according to Babayaga3.5 generator document [1]
- Cosine theta changed from 0.8 to 0.78
- Deposited energy in EMC changed 0.05 GeV around $0.35E_{\text{cm}}$ GeV
- Difference results with and without back to back cuts
- Background Error and Beam energy bias
- MC statistics and trigger efficiency[2]

Event selection cuts

Systematic error analysis

Beam energy uncertainty

E (normal)	Lum.	E (calab.)	Lum.	δ	E (normal)	Lum.	E (calab.)	Lum.	δ
2.0000	10.076	2.0043	10.064	0.0030	2.6444	33.722	2.6475	33.616	0.0015
2.0500	3.343	2.0536	3.339	0.0030	2.6464	34.003	2.6499	34.048	0.0005
2.1000	12.167	2.1041	12.171	0.0005	2.7000	1.034	2.7021	1.032	0.0029
2.1500	2.841	2.1543	2.850	-0.0014	2.8000	1.008	2.8014	1.008	0.0010
2.1750	10.627	2.1783	10.617	0.0023	2.9000	105.253	2.9028	105.085	0.0043
2.2000	13.699	2.2041	13.644	0.0050	2.9500	15.942	2.9517	15.992	-0.0026
2.2324	11.856	2.2360	11.889	-0.0014	2.9810	16.071	2.9822	16.048	0.0032
2.3094	21.108	2.3128	21.185	-0.0029	3.0000	15.881	3.0012	15.828	0.0053
2.3864	22.549	2.3909	22.688	-0.0046	3.0200	17.290	3.0211	17.319	-0.0008
2.3960	66.868	2.4003	66.747	0.0026	3.0800	126.185	3.0817	126.724	-0.0023
2.5000	1.098	2.5034	1.096	0.0036					

Systematic error of all sources

2.0000GeV

Source	Sys. Error (%)	notes
Track efficiency	0.17	
Cluster recon.	0.13	
Beam energy	0.30	
Generator	0.50	
MC statistics	0.21	
Trigger efficiency	0.10	
Back to back cuts	0.18	
Costheta < 0.8	0.06	
emc cuts	0.20	
Total	0.72	

Systematic error on all energy points

Ecm(GeV)	cos θ	emcut	beam	mcsta	trigg	gen	track	reclust	bktobk	Total
2.0000	0.0006	0.0020	0.0030	0.0021	0.001	0.005	0.0017	0.0013	0.0018	0.0072
2.0500	0.0003	0.0021	0.0030	0.0021	0.001	0.005	0.0018	0.0014	0.0018	0.0072
2.1000	0.0004	0.0012	0.0005	0.0021	0.001	0.005	0.0023	0.0011	0.0008	0.0063
2.1500	0.0007	0.0039	0.0014	0.0021	0.001	0.005	0.0025	0.0016	0.0018	0.0078
2.1750	0.0006	0.0012	0.0023	0.0021	0.001	0.005	0.0014	0.0007	0.0014	0.0065
2.2000	0.0006	0.0015	0.0050	0.0021	0.001	0.005	0.0011	0.0012	0.0010	0.0079
2.2320	0.0003	0.0013	0.0014	0.0021	0.001	0.005	0.0024	0.0006	0.0013	0.0065
2.3090	0.0000	0.0026	0.0029	0.0021	0.001	0.005	0.0026	0.0015	0.0008	0.0074
2.3860	0.0003	0.0009	0.0046	0.0021	0.001	0.005	0.0039	0.0016	0.0015	0.0085
2.3960	0.0015	0.0000	0.0026	0.0021	0.001	0.005	0.0024	0.0014	0.0008	0.0069
2.5000	0.0009	0.0018	0.0036	0.0021	0.001	0.005	0.0046	0.0011	0.0018	0.0085
2.6440	0.0005	0.0003	0.0015	0.0021	0.001	0.005	0.0025	0.0013	0.0016	0.0066
2.6460	0.0006	0.0035	0.0005	0.0021	0.001	0.005	0.0031	0.0018	0.0018	0.0077
2.7000	0.0019	0.0000	0.0029	0.0021	0.001	0.005	0.0029	0.0013	0.0010	0.0073
2.8000	0.0010	0.0020	0.0010	0.0021	0.001	0.005	0.0030	0.0007	0.0010	0.0068
2.9000	0.0012	0.0038	0.0043	0.0021	0.001	0.005	0.0011	0.0007	0.0027	0.0086
2.9500	0.0002	0.0009	0.0026	0.0021	0.001	0.005	0.0021	0.0018	0.0005	0.0068
2.9810	0.0001	0.0001	0.0032	0.0021	0.001	0.005	0.0001	0.0010	0.0017	0.0067
3.0000	0.0005	0.0009	0.0053	0.0021	0.001	0.005	0.0031	0.0011	0.0019	0.0086
3.0200	0.0005	0.0027	0.0008	0.0021	0.001	0.005	0.0028	0.0011	0.0009	0.0070
3.0800	0.0006	0.0039	0.0023	0.0021	0.001	0.005	0.0012	0.0014	0.0019	0.0076

Luminosity Results for all energy points

Ecm(GeV)	$\mathcal{L}$ (pb ⁻¹)	Ecm(GeV)	$\mathcal{L}$ (pb ⁻¹)
2.0000	$10.074 \pm 0.005 \pm 0.073$	2.6444	$33.722 \pm 0.013 \pm 0.223$
2.0500	$3.343 \pm 0.003 \pm 0.024$	2.6464	$34.003 \pm 0.013 \pm 0.262$
2.1000	$12.167 \pm 0.006 \pm 0.077$	2.7000	$1.034 \pm 0.002 \pm 0.008$
2.1500	$2.841 \pm 0.003 \pm 0.022$	2.8000	$1.008 \pm 0.002 \pm 0.007$
2.1750	$10.625 \pm 0.006 \pm 0.069$	2.9000	$105.253 \pm 0.025 \pm 0.905$
2.2000	$13.699 \pm 0.007 \pm 0.108$	2.9500	$15.942 \pm 0.010 \pm 0.108$
2.2324	$11.856 \pm 0.007 \pm 0.077$	2.9810	$16.071 \pm 0.010 \pm 0.108$
2.3094	$21.089 \pm 0.009 \pm 0.156$	3.0000	$15.881 \pm 0.010 \pm 0.137$
2.3864	$22.549 \pm 0.010 \pm 0.192$	3.0200	$17.290 \pm 0.011 \pm 0.121$
2.3960	$66.869 \pm 0.017 \pm 0.461$	3.0800	$126.185 \pm 0.029 \pm 0.959$
2.5000	$1.098 \pm 0.002 \pm 0.009$		

Summary

- ① Integrated Luminosity for 2-3 GeV energy region (data taken from Dec. 30 2014 to April 30 2015) have been measured under BOSS665p01 version (see Results page 23 in detail)
- ② Systematic error for all the energy points is less than 1%

Thank your attention !

Reference documents

1. Giovanni Balossini, Carlo M Carloni calame, Guido Montagna,Oreste Nicrosiniand Fulvio Piccinini, Nucl. Phys.,2006, B758: 227.
2. Trigger effciencies at BES-III, N.Berger, Zhu Kai et al. Chinese Physics C 34(12) (2010) 1779-1784.

Comparison with different version

Ecm(GeV) 665p01 665 δ				Ecm(GeV) 665p01 665 δ			
2.0000	10.074	10.052	0.002	2.6444	33.722	33.730	-0.000
2.0500	3.343	3.356	-0.004	2.6464	34.003	34.000	0.000
2.1000	12.167	12.096	0.006	2.7000	1.034	1.036	-0.002
2.1500	2.841	2.839	0.001	2.8000	1.008	1.004	0.004
2.1750	10.626	10.625	0.000	2.9000	105.253	105.225	0.000
2.2000	13.699	13.657	0.003	2.9500	15.942	16.025	-0.005
2.2320	11.856	11.936	-0.007	2.9810	16.071	16.059	0.001
2.3090	21.089	21.035	0.003	3.0000	15.881	15.877	0.000
2.3864	22.549	22.693	-0.006	3.0200	17.290	17.333	-0.002
2.3960	66.869	67.022	-0.002	3.0800	126.185	119.398	0.054
2.5000	1.098	1.100	-0.002				