Integrated Luminosity of the XYZ data

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Outline

Introduction

Introduction

- To better understand XYZ states, BESIII has taken around 3.7 fb^{-1} data at 8 energy points in 2017.
- Also, it was recently discovered that the published luminosity of 2011-2014 XYZ data is incorrect because a problem concerning detector malfunction was overlooked by the previous analysis.
- This work presents the result of the luminosity of the 2017 XYZ data as well as an update on the 2011-2014 XYZ data.

Luminosity of 2017 XYZ Data

Data Sets of 2017 XYZ Data

- BOSS Version: 7.0.3
- Eight energy points:

Data Sets(MeV)	Run Numbers	Online Luminosity(pb^{-1})
4190	47543-48170	483
4200	48172-48713	496
4210	48714-49239	497
4220	49270-49787	498
4237	49788-50254	504
4246	50255-50793	505
4270	50796-51302	499
4280	51305-51498	175

Event Selection and MC Samples

Event Selection for Bhabha

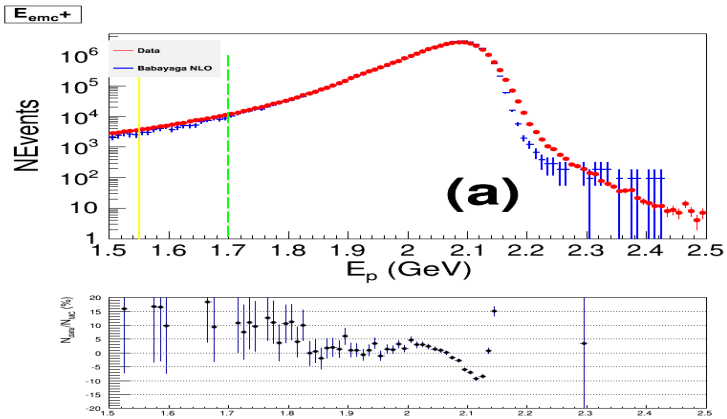
- 2 good charged tracks, 0 net charge.
- $E_{e^-}, E_{e^+} > \frac{1.55}{4.19} \times E_{cm}$
- $|cos\theta_{e^-}^{MDC}|, |cos\theta_{e^+}^{MDC}| < 0.8$
- $P_{e^-}, P_{e^+} > \frac{1.95}{4.19} \times E_{cm}$
- $m(e^+e^-) > 3.85 GeV$

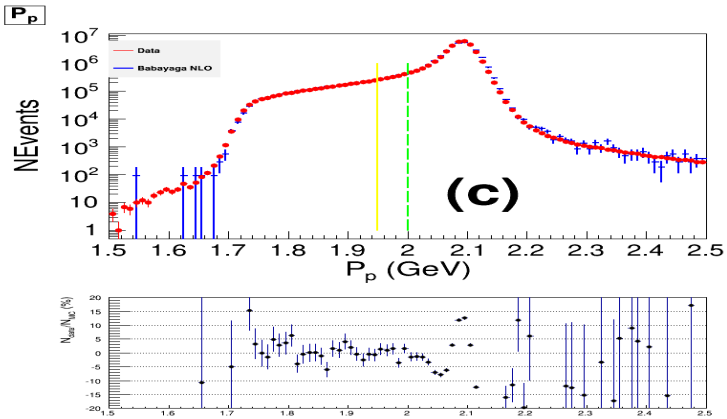
MC Samples

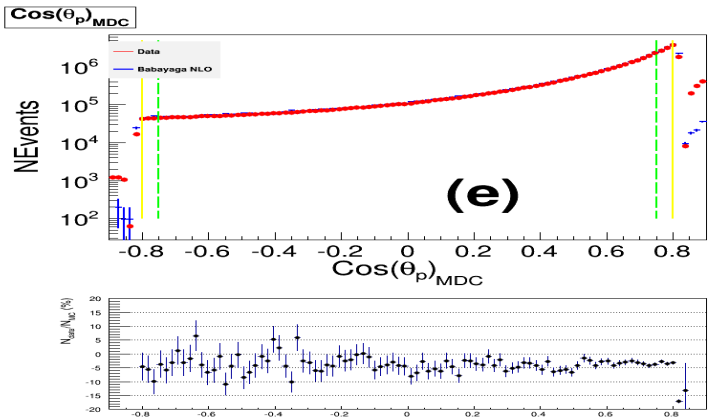
- 2 million Bhabha events for each energy point.
- Babayaga@NLO package with a user cut: requiring $m(e^+e^-) > 3.8$ GeV, to avoid sampling over narrow resonances like J/ψ, ψ', etc.

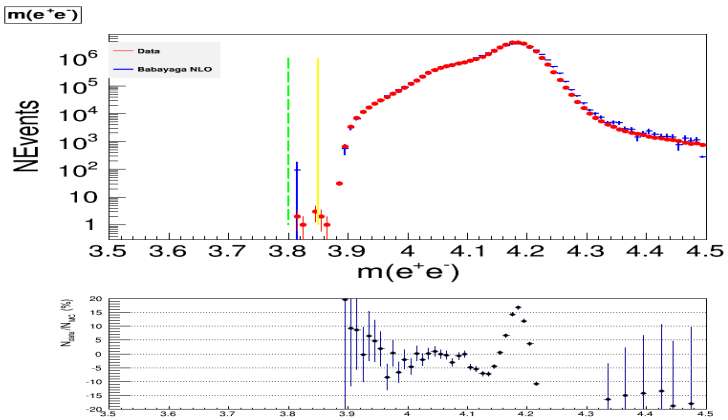
Relevant Distributions

The distribution of the quantities used for the event selection, with lines representing standard cuts and alternative cuts.









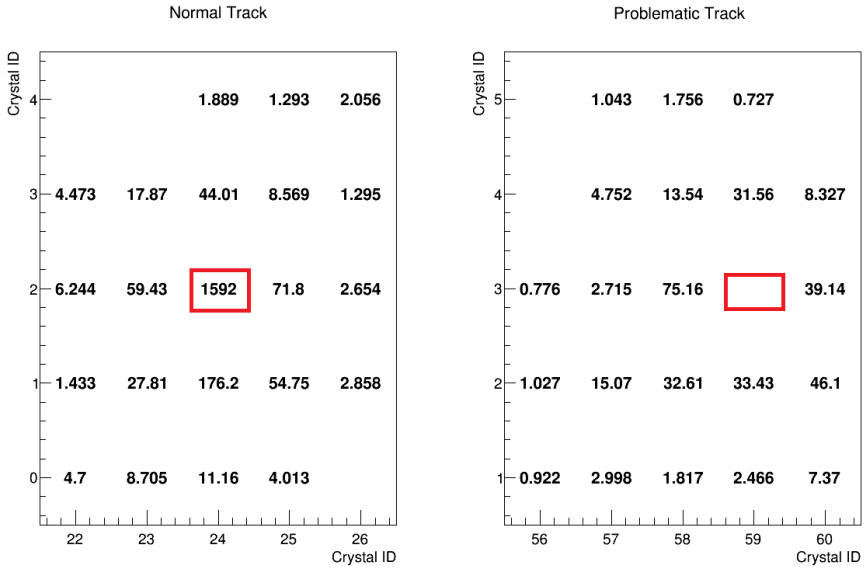
Immediate Result before correction

Table: The cross section of Bhabha process, number of events, efficiency and luminosity

Data Set(MeV)	CM Energy(MeV)	$\sigma_{Bhabha}(\mathrm{nb})$	efficiency(%)	nEvents(mil.)	Lum.$(\mathrm{pb}^{-}1)$
4190	4189.3	354.82	17.67	32.62	523.9
4200	4199.6	353.88	17.53	32.59	525.2
4210	4209.7	352.98	17.37	31.73	517.2
4220	4218.8	352.42	17.38	31.45	513.4
4237	4235.8	350.79	17.41	32.32	529.1
4246	4243.9	350.26	17.38	32.65	536.3
4270	4266.9	348.01	17.28	31.86	529.7
4280	4277.8	346.92	17.21	10.46	175.2

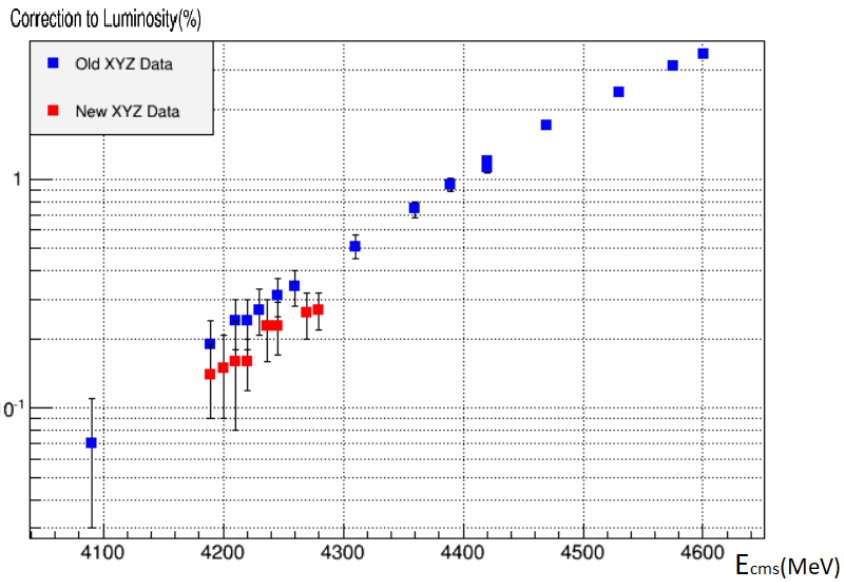
EMC Readout Problem

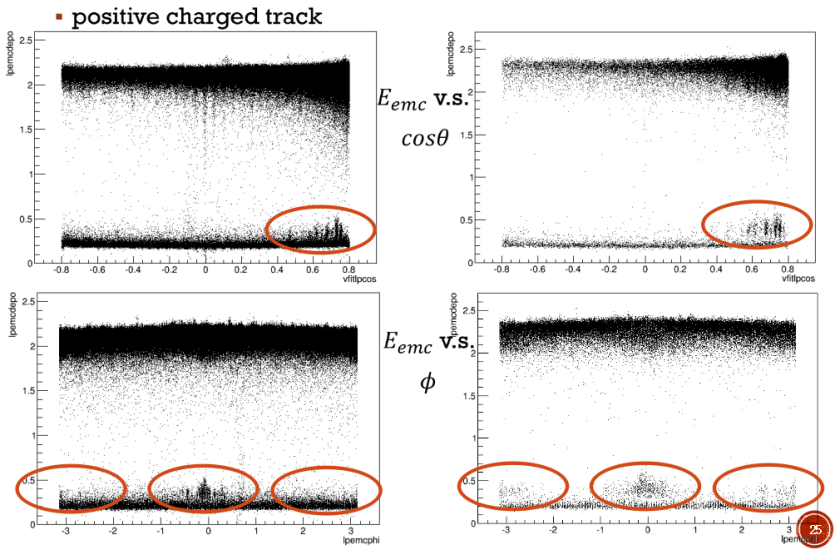
- It was recently found out that for tracks above 2 GeV, the crystals in EMC would occasionally give 0 readout.
- The cause of the problem is unknown, and it's not simulated in MC.
- The problem leads to an underestimation of the luminosity.



EMC Readout Problem - Scale and Angular Distribution

- As the energy increase, the impact of the problem grows exponentially.
- Crystals in certain (θ,ϕ) area are affected.

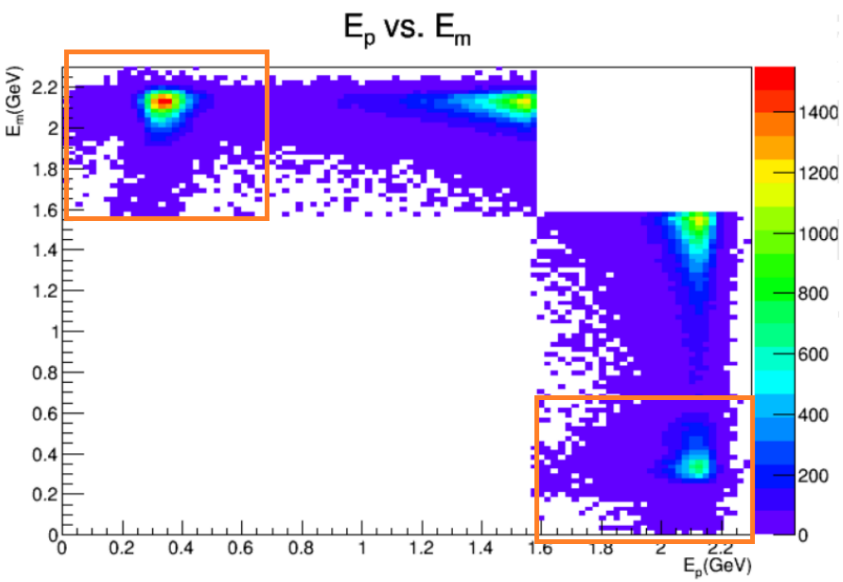


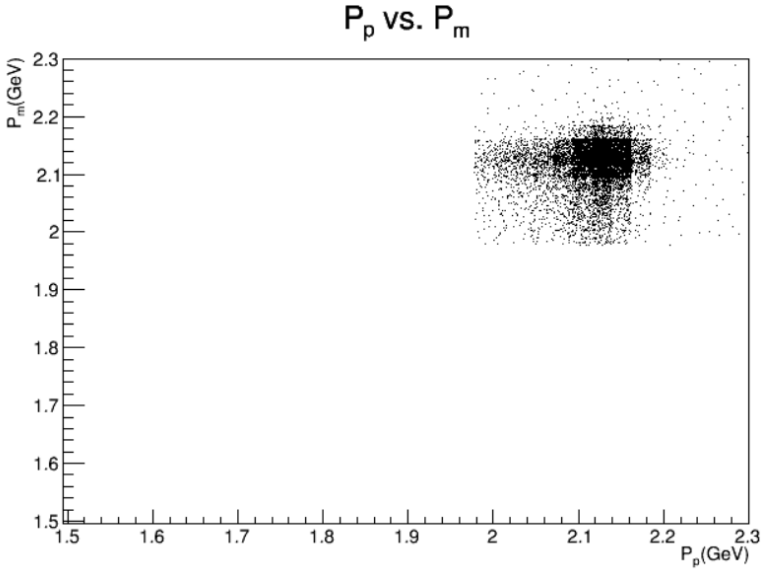


Correction Method 1

Recover the events passing the criterion

- 2 opposite charged tracks: $|cos\theta_{MDC}| < 0.8$, $P > \frac{1.95}{4.19} \times E_{cm}$
- $m(e^+e^-) > 3.85 GeV$
- $E > \frac{1.55}{4.19} E_{cm}$ for one track, and $E < \frac{0.62}{4.19} E_{cm}$ for the other

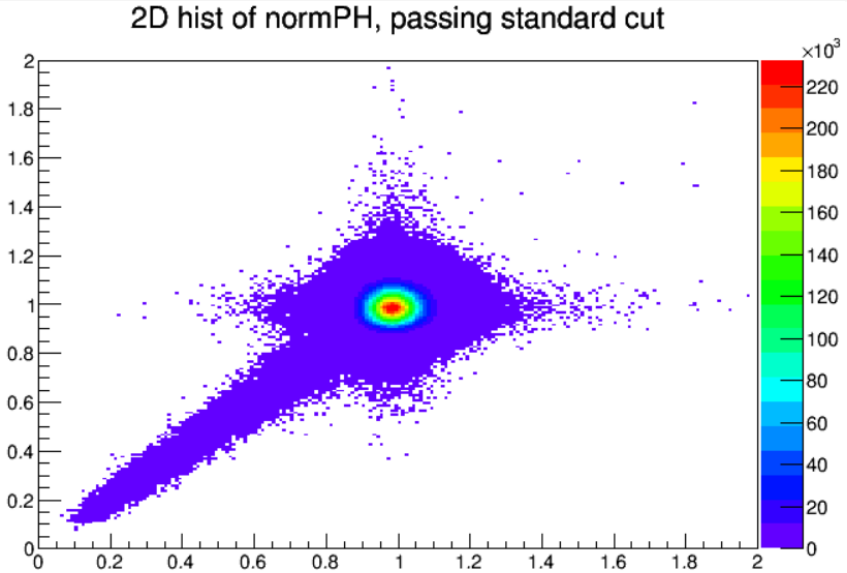




Correction Method 2

Fit the 2d-hist of ($normPH_p$,$normPH_m$)

- $E < \frac{1.55}{4.19} \times E_{beam}$ for at least one track; all other requirements remain the same.
- Fit with Bhabha component, di-muon component, and a uniform background.



Correction Result

The result of the Method 1 is used for the correction, and its difference to the result of Method 2 is to be used for the estimation of the systematic error.

Table: The correction to account for the events left out because of missing EMC readouts.

Energy Point(GeV)	4.190	4.200	4.210	4.220	4.237	4.246	4.270	4.280
Events to Recover	43811	49426	50164	49621	71918	71168	82409	27817
Lum. Correction(pb^{-1})	0.7	0.8	0.8	1.2	1.2	1.8	1.4	0.5
Percentage(%)	0.14	0.15	0.16	0.16	0.23	0.23	0.26	0.27

Composition of Systematic Uncertainty

- Tracking efficiency: alternative selection criterion that only uses EMC info.
- Energy Bias: change E_{beam} by 0.3 MeV; get efficiency and cross section through extrapolation.
- Requirement on E: alternative cut at $\frac{1.7}{4.19} \times E_{cm}$.
- Requirement on $Cos\theta$: alternative range of [-0.75,0.75].
- Requirement on P: alternative cut at $\frac{2}{4.19} \times E_{cm}$.
- Requirement on $M(e^+e^-)$: alternative cut at 3.8 GeV.
- Babayaga@NLO generator: quote the authors' claim of 0.1%.
- Cross section: given by the generator, negligible.
- MC Statistics: 0.2% (2 mil. events, 17% efficiency).
- Correction to EMC Readout Problem: difference of two correction methods.

Systematic Error of Tracking Efficiency

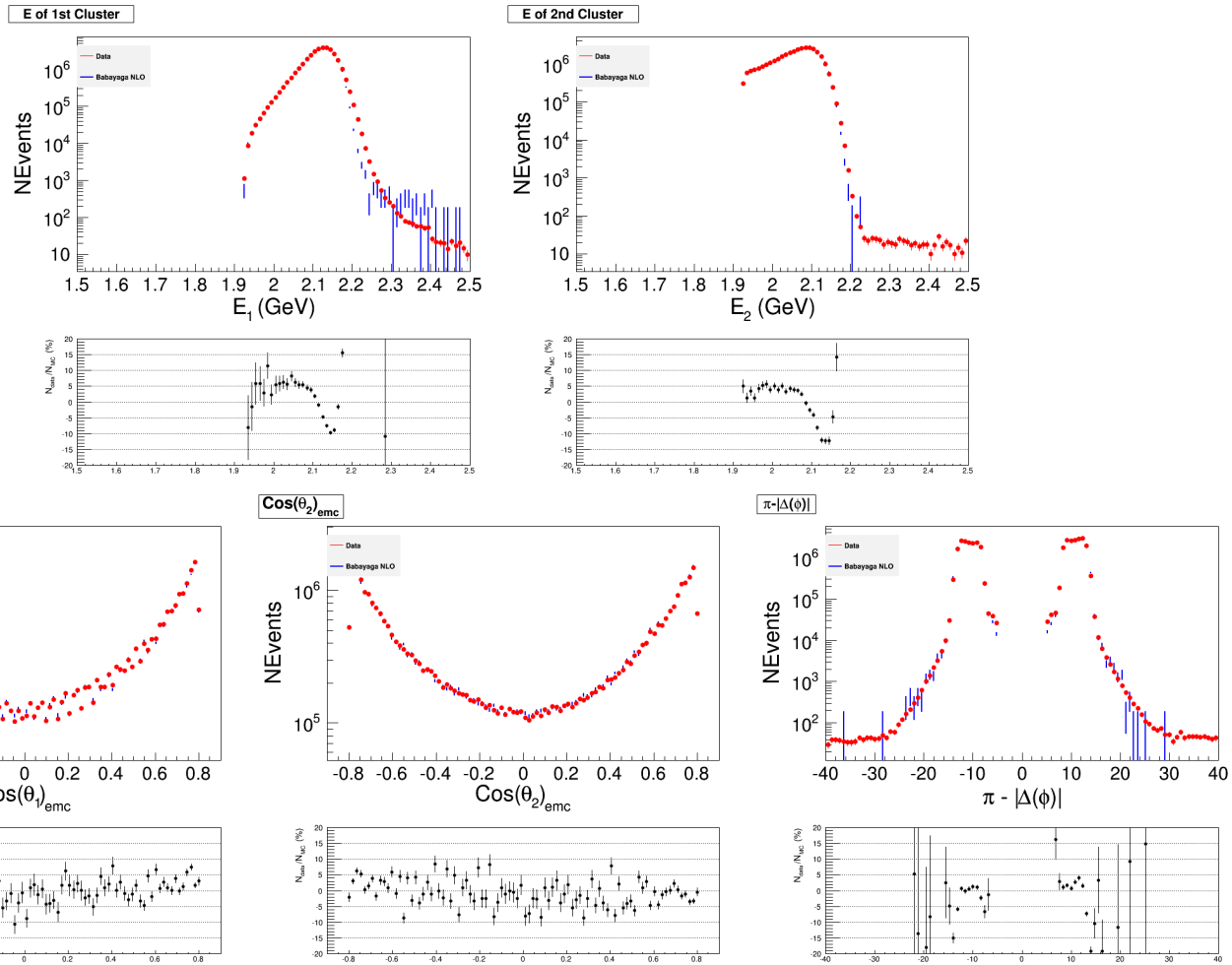
Alternative selection criterion that only uses EMC info

- At least two EMC clusters, the most energetic two marked as cluster 1 and cluster 2
- $E_{1,2} > \frac{1.9}{4.19} E_{cm}$
- $|cos\theta_{1,2}^{EMC}| < 0.8$
- $5^\circ < |\Delta\phi| < 40^\circ$, where $\Delta\phi$ is $|\phi_1 - \phi_2| - 180^\circ$

Table: The corresponding Luminosity

Energy Point(GeV)	4.190	4.200	4.210	4.220	4.237	4.246	4.270	4.280
Event Number(mil.)	34.04	33.93	33.21	32.79	33.54	33.86	33.00	10.82
MC Efficiency(%)	18.28	18.22	18.18	18.10	18.03	17.99	17.91	17.75
MethodII Luminosity(pb^{-1})	524.6	526.1	517.5	513.8	530.4	537.2	531.4	175.7
Difference from Standard Result(%)	0.13	0.17	0.05	0.08	0.24	0.15	0.30	0.29

Tracking Efficiency - Relevant Distributions



Summary of Systematic Uncertainties

	4190	4200	4210	4220	4237	4246	4270	4280
Tracking Efficiency	0.13	0.17	0.05	0.08	0.24	0.15	0.30	0.29
On E Cuts(%)	0.12	0.11	0.12	0.14	0.09	0.12	0.13	0.10
On Cosθ Cuts(%)	0.24	0.22	0.21	0.22	0.32	0.37	0.43	0.39
On P Cuts(%)	0.14	0.08	0.01	0.00	0.17	0.06	0.09	0.01
On M(ee) Cuts(%)	0							
Energy Bias(%)	0.06	0.07	0.00	0.01	0.04	0.04	0.02	0.01
Babayaga NLO Generator(%)	0.1							
MC Statistics(%)	0.2							
Correction to Missing EMC Readout	0.05	0.06	0.08	0.04	0.07	0.06	0.06	0.05
Combined(%)	0.41	0.39	0.35	0.35	0.45	0.50	0.59	0.55

Overall Result of 2017 XYZ Data

Energy Point(MeV)	Run Number	Result(pb^{-1})
4190	47543-48170	$524.6 \pm 0.1 \pm 2.2$
4200	48172-48713	$526.0 \pm 0.1 \pm 2.1$
4210	48714-49239	$518.0 \pm 0.1 \pm 1.8$
4220	49270-49787	$514.6 \pm 0.1 \pm 1.8$
4237	49788-50254	$530.3 \pm 0.1 \pm 2.4$
4246	50255-50793	$538.1 \pm 0.1 \pm 2.7$
4270	50796-51302	$531.1 \pm 0.1 \pm 3.1$
4280	51305-51498	$175.7 \pm 0.1 \pm 1.0$

Update on 2011-2014 XYZ Data

Motivation, Data Sets, and Procedure

Motivation

- Correction to EMC readout problem.
- Slightly data files in BOSSv703 data sets.

Procedure

- The analysis is conducted in the same way as the 2017 data.
- The luminosity of 3810, 3900, 4009 data sets are not updated.

Index	E_{cm}(MeV)	Run Numbers
1	4009	23463-24141
2	4260_1	29677-30367
3	4190	30372-30437
4	4230_1	30438-30491
5	4310	30492-30557
6	4360	30616-31279
7	4390	31281-31325
8	4420_1	31327-31390
9	4260_2	31561-31981
10	4210	31983-32045
11	4220	32046-32140
12	4245	32141-32226
13	4230_2	32239-33484
14	3810	33490-33556
15	3900	33572-33657
16	4090	33659-33719
17	4420_2	36773-38140
18	4470	36245-36393
19	4530	36398-36588
20	4575	36603-36699
21	4600	35227-36213

Luminosity for BOSSv703 Data Sets

Data Sets(MeV)	EMC Correction(%)	Updated Result(pb^{-1})	Previous Result(pb^{-1})	Difference(%)
3810	-	-	50.54 ± 0.03	-
3900	-	-	52.61 ± 0.03	-
4009	-	-	481.96 ± 0.10	-
4090	0.07	52.86 ± 0.03	52.63 ± 0.03	+0.43
4190	0.19	43.33 ± 0.03	43.09 ± 0.03	+0.56
4210	0.24	54.95 ± 0.03	54.55 ± 0.03	+0.73
4220	0.24	54.60 ± 0.03	54.13 ± 0.03	+0.86
4230_1	0.27	44.54 ± 0.03	44.40 ± 0.03	+0.32
4230_2	0.27	1056.37 ± 0.13	1047.34 ± 0.14	+0.86
4245	0.31	55.88 ± 0.03	55.59 ± 0.04	+0.53
$4260_{1,2}$	0.34	828.36 ± 0.12	523.74 ± 0.10 301.93 ± 0.08	+0.32
4310	0.51	45.08 ± 0.03	44.90 ± 0.03	+0.40
4360	0.74	543.94 ± 0.10	539.84 ± 0.10	+0.76
4390	0.95	$55.57 \pm \pm 0.04$	55.18 ± 0.04	+0.70
4420_1	1.13	46.80 ± 0.03	44.67 ± 0.03	+4.77
4420_2	1.20	1043.86 ± 0.13	1028.89 ± 0.13	+1.45
4470	1.71	111.09 ± 0.04	109.94 ± 0.04	+1.05
4530	2.38	112.12 ± 0.04	109.98 ± 0.04	+1.95
4575	3.13	48.93 ± 0.03	47.67 ± 0.03	+2.64
4600	3.51	586.89 ± 0.11	566.93 ± 0.11	+3.52

Luminosity for BOSSv6.6.x Data Sets

The file lists of the XYZ data sets in BOSSv703 differ slightly from BOSSv6.6.x because a few dozen files were recovered in the data reconstruction for the newer BOSS version.
The luminosity of the older BOSS versions is measured in BOSSv703, but with the data lists tailored accordingly.

Data Sets	N(files) in BOSS v6.6.x	N(files) in BOSS v7.0.3	Lum. for BOSS v6.6.x(pb^{-1})
4230_2	12955	12982	1053.92 ± 0.13
4420_1	466	480	45.37 ± 0.03
4420_2	10899	10925	1041.27 ± 0.13
4600	6953	6976	585.35 ± 0.11
Others	34238	34238	same

Systematic Uncertainty

Source	Relative Uncertainties(%)
Tracking Efficiency	0.42
Energy Cuts	0.28
Momentum Cuts	0.29
$Cos\theta$ Cuts	0.14
Beam Energy	0.07
Babayaga NLO Generator	0.1
MC Statistics	0.2
Correction to Missing EMC Readout	0.15
Total	0.66

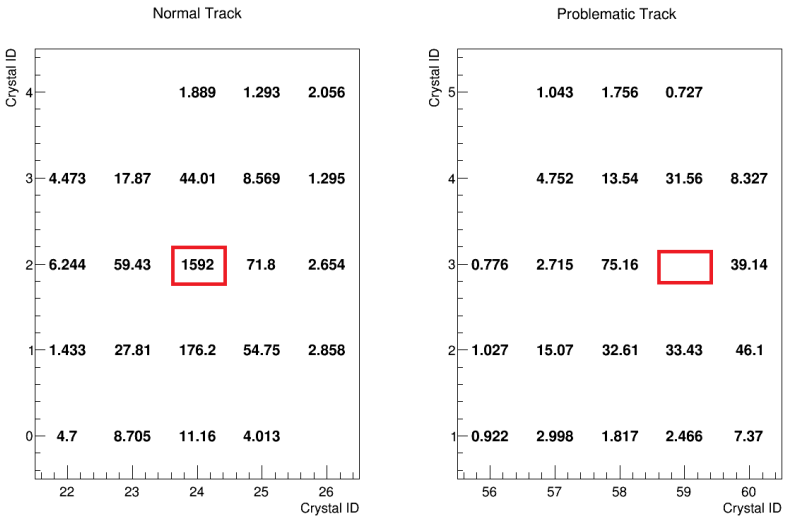
- Each term uses the maximum value across all energy points.
- Quoted from the previous analysis, the systematic uncertainty of the 3810, 3900 and 4009 data sets are 0.97%

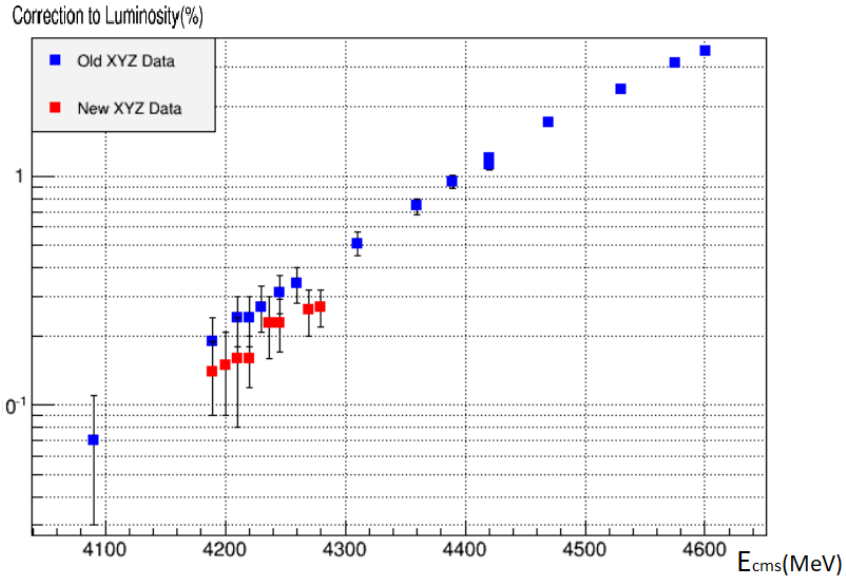
Overall Results of 2011-2014 Data

Energy Point(MeV)	Run Number	Result BOSS v7.0.3(pb^{-1})	Result BOSS v6.6.x(pb^{-1})
4009	23463-24141	$482.0 \pm 0.1 \pm 4.7$	-
4190	30372-30437	$43.33 \pm 0.03 \pm 0.29$	-
4230_1	30438-30491	$44.54 \pm 0.03 \pm 0.29$	-
4310	30492-30557	$45.08 \pm 0.03 \pm 0.30$	-
4360	30616-31279	$543.9 \pm 0.1 \pm 3.6$	-
4390	31281-31325	$55.57 \pm 0.03 \pm 0.37$	-
4420_1	31327-31390	$46.80 \pm 0.03 \pm 0.31$	$45.37 \pm 0.03 \pm 0.30$
$4260_{1,2}$	29677-30367, 31561-31981	$828.4 \pm 0.1 \pm 5.5$	-
4210	31983-32045	$54.95 \pm 0.03 \pm 0.36$	-
4220	32046-32140	$54.60 \pm 0.03 \pm 0.36$	-
4245	32141-32226	$55.88 \pm 0.03 \pm 0.37$	-
4230_2	32239-33484	$1056.4 \pm 0.1 \pm 7.0$	$1053.9 \pm 0.1 \pm 7.0$
3810	33490-33556	$50.54 \pm 0.03 \pm 0.49$	-
3900	33572-33657	$52.61 \pm 0.03 \pm 0.51$	-
4090	33659-33719	$52.86 \pm 0.03 \pm 0.35$	-
4420_2	36773-38140	$1043.9 \pm 0.1 \pm 6.9$	$1041.3 \pm 0.1 \pm 6.9$
4470	36245-36393	$111.09 \pm 0.04 \pm 0.73$	-
4530	36398-36588	$112.12 \pm 0.04 \pm 0.74$	-
4575	36603-36699	$48.93 \pm 0.03 \pm 0.32$	-
4600	35227-36213	$586.9 \pm 0.1 \pm 3.9$	$585.4 \pm 0.1 \pm 3.9$

Summary

The EMC Readout Problem





- The linear relationship, what does it imply?
- The problem may grow to be severe if BESIII is to operate above 4.6 GeV.

Summary

- Observation and correction to the EMC readout problem.
- Measured the luminosity of 2017 XYZ Data, with a precision of 0.6%.
- Updated the Luminosity of 2011-2014 XYZ Data.