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: Ecm (2.000GeV ~3.080 GeV 21 energy points)**

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

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

  500000 $e^+e^-\to\mu^+\mu^-$ (babayaga)

  500000 $e^+e^-\to$hadrons (lundarlw+eclusive)

  500000 $e^+e^-\to e^+ e^-$ 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_{good}>=2)

a) Vr<1cm , |Vz|<10cm

b) Momentum of each track less than 2.0GeV

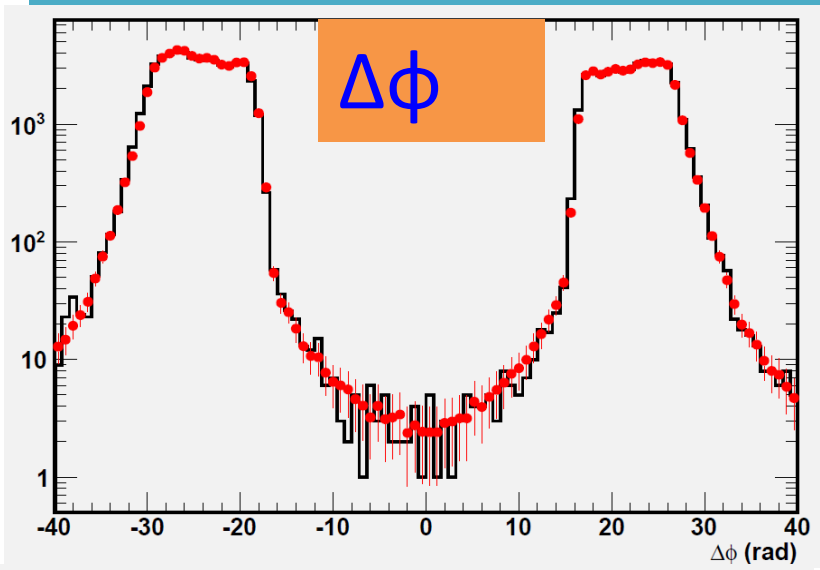
- Deposited energy of each charged track in EMC great than 0.35E_{cm} GeV
- Absolute cosine theta of each charged track less than 0.8

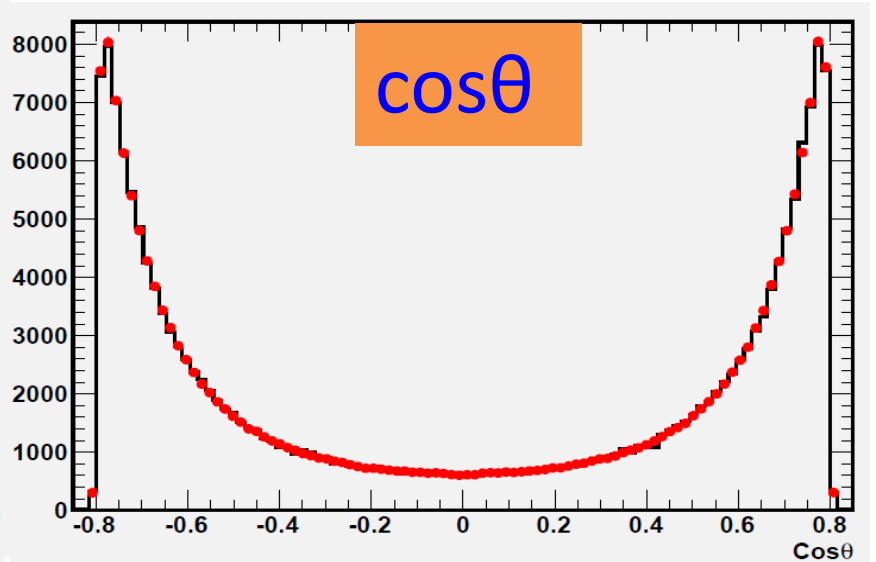
Background estimation(2.000GeV)

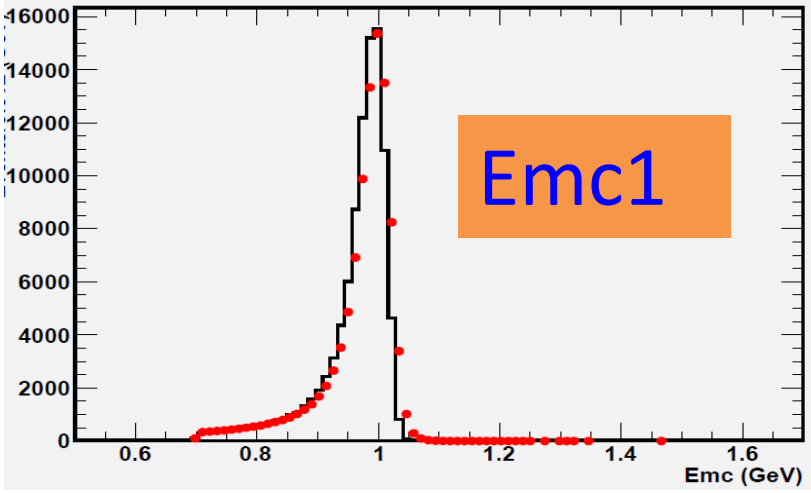
Item	$e^+e^- \to \gamma\gamma$	$e^+e^- \to \mu^+\mu^-$	$e^+e^- \to e^+e^-X$	$e^+e^- \to$ hadrons
ϵ^b	3.6e-5	8.0e-6	3.4e-4	3.6e-5
σ^b	87.0	22.4	1.5	56.0
N_b	32	2	5	20

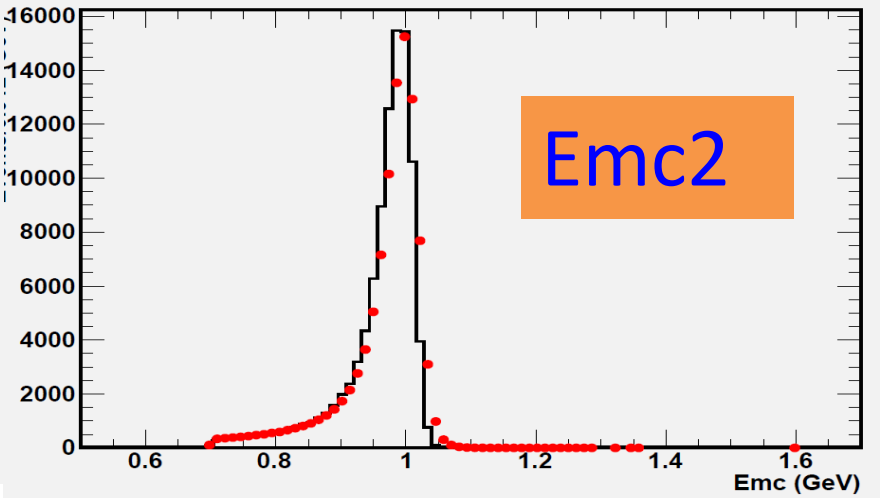
The ratio of background to signal events is 1.7e-5 (Lum=10.134pb^-1)

Some distribution comparison









Luminosity calculation

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

$$\mathcal{L}^{2.0000} = 10.051 \pm 0.005 \left(pb^{-1}\right)$$

N_s = 3608921 N_{bkg} = 61

σ^s =1839.37 $\pm$ 1.37 (nb)

ϵ^s = 0.1952 $\pm$ 0.0006

Integrated luminosity for all energy points (I)

Ecm(GeV)	σ (nb)	ε	Nsig/N_{bkg}	$\mathcal{L}$ (pb^{-1}) offline	$\mathcal{L}$ (pb^{-1}) online	Difference(%)
2.0000	1839.37	0.1952	3608921/60	10.054 ± 0.005	9.306	8.0
2.0500	1752.22	0.1945	1137161/18	3.337 ± 0.003	3.018	10.6
2.1000	1669.96	0.1936	3938414/52	12.183 ± 0.006	11.348	7.4
2.1500	1593.50	0.1941	878352/10	2.840 ± 0.003	2.755	3.1
2.1750	1556.69	0.1943	3190890/53	10.552 ± 0.006	10.056	4.9
2.2000	1521.17	0.1934	4032158/89	13.707 ± 0.007	13.005	5.4
2.2324	1477.74	0.1937	3400520/47	11.877 ± 0.006	11.248	5.6
2.3094	1381.87	0.1936	5560268/97	20.782 ± 0.009	20.482	1.5
2.3864	1294.86	0.1939	5668928/92	22.584 ± 0.009	22.059	2.4
2.3960	1284.14	0.1935	16628266/152	66.903 ± 0.016	64.841	3.2
2.5000	1180.97	0.1942	251374/5	1.096 ± 0.002	1.044	5.0

Integrated luminosity for all energy points(II)

Ecm(GeV)	σ (nb)	ε	Nsig/N_{bkg}	$\mathcal{L}$ (pb^{-1}) offline	$\mathcal{L}$ (pb^{-1}) online	Difference(%)
2.6444	1055.36	0.1941	6888838/152	33.634 ± 0.013	32.530	3.4
2.6464	1053.81	0.1944	6975616/130	34.047 ± 0.013	33.730	0.9
2.7000	1012.55	0.1943	203222/3	1.033 ± 0.002	0.987	4.7
2.8000	941.14	0.1939	183939/4	1.008 ± 0.002	0.965	4.5
2.9000	878.14	0.1947	18031529/353	105.458 ± 0.025	102.096	3.3
2.9500	848.57	0.1956	2639667/63	15.905 ± 0.010	15.696	1.3
2.9810	831.25	0.1935	2596626/67	16.139 ± 0.010	15.391	4.9
3.0000	820.82	0.1937	2532909/69	15.932 ± 0.010	15.269	4.3
3.0200	810.15	0.1946	2728534/65	17.306 ± 0.010	16.605	4.2
3.0800	778.54	0.1941	18214384/467	120.558 ± 0.028	116.424	3.6

Luminosity measurement check with $e^+e^- \to \Upsilon\,\Upsilon$

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 0.58 Ecm GeV energy points.
- $|\cos\theta|<0.8$
- The number of charged track is zero
- $|\Delta\phi| < 2.5$ (degree) $\Delta\phi = |\phi_1 - \phi_2| - 180^0$

  ϕ is the azimuthal angle in EMC .

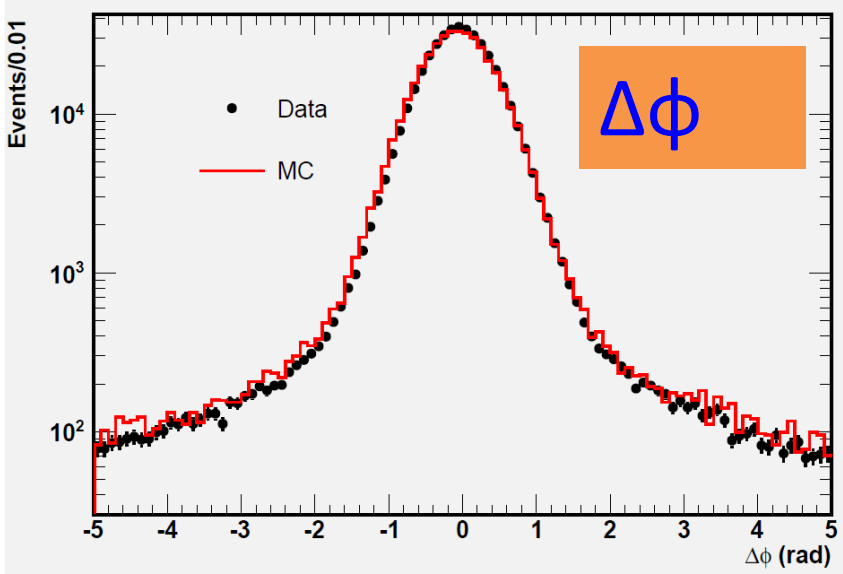
  $2.5<|\Delta\phi| < 5$ (sideband region)

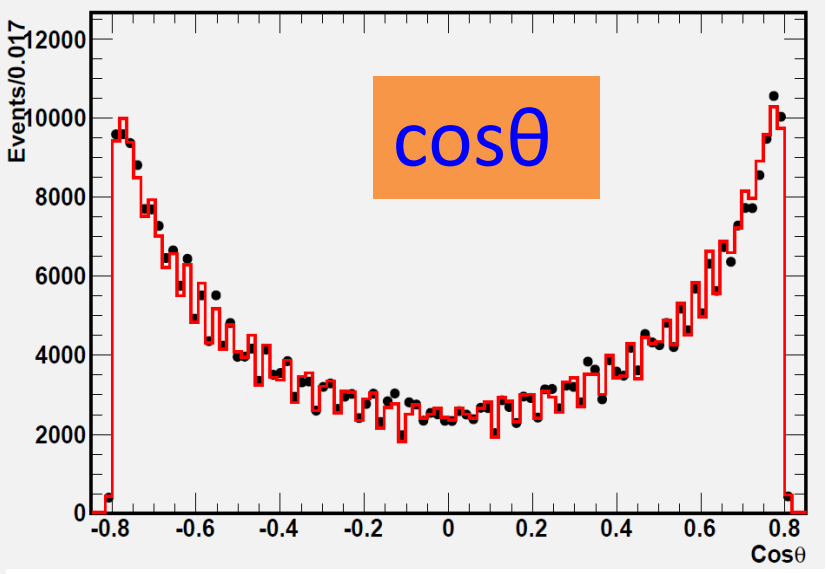
Background estimation(2.000GeV)

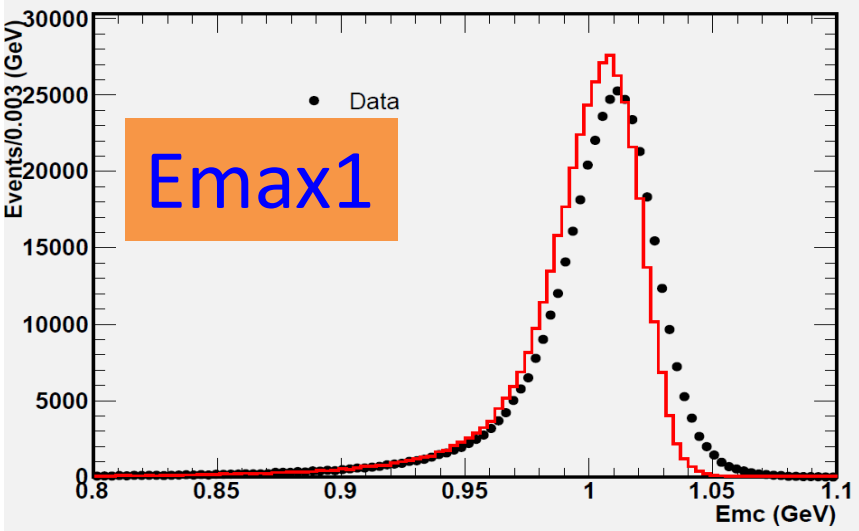
Item	$e^+e^- \to e^+e^-$	$e^+e^- \to \mu^+\mu^-$	$e^+e^- \to e^+e^-X$	$e^+e^- \to$ hadrons
ϵ^b	1.6e-5	0.000	0.000	2.2e-5
σ^b	1840.0	22.4	1.5	56.0
N_b	298	0	0	13

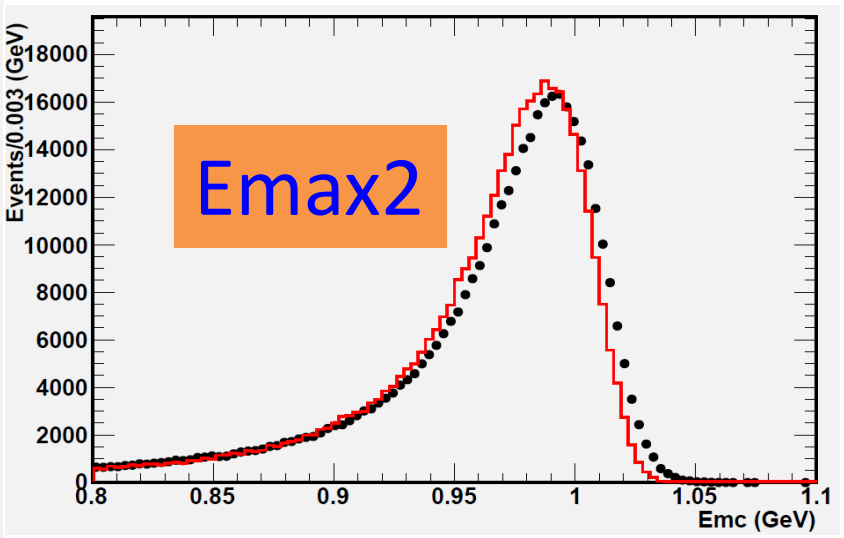
The ratio of background to signal events is 7.4e-4 (Lum=10.134pb^-1)

Some distribution comparison









Luminosity calculation

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

$$\mathcal{L}^{2.0000} = 10.134 \pm 0.016 (pb^{-1})$$

where : N_s = 416770 N_{sid} = 5871

σ^s =87.36 $\pm$ 0.09 (nb)

ϵ^s = 0.4641 $\pm$ 0.0007

Integrated luminosity for all energy points (I)

Ecm(GeV)	σ (nb)	ε	Nsig/Nsid	$\mathcal{L}$ (pb^{-1})	notes
2.0000	87.36	0.4641	416770/5871	10.134 ± 0.016	
2.0500	83.17	0.4646	131217/1791	3.350 ± 0.009	
2.1000	79.32	0.4635	452305/6106	12.137 ± 0.018	
2.1500	75.67	0.4632	101407/1370	2.854 ± 0.009	
2.1750	73.96	0.4649	368216/5048	10.561 ± 0.018	
2.2000	72.34	0.4646	463284/6136	13.602 ± 0.020	
2.2324	70.26	0.4633	390715/5465	11.836 ± 0.019	
2.3094	65.67	0.4626	638834/8631	20.745 ± 0.026	
2.3864	61.54	0.4635	651506/8748	22.537 ± 0.028	
2.3960	61.06	0.4612	1907801/25406	66.854 ± 0.049	
2.5000	56.10	0.4635	28852/364	1.095 ± 0.006	

Integrated luminosity for all energy points(II)

Ecm(GeV)	σ (nb)	ε	Nsig/Nsid	$\mathcal{L}$ (pb^{-1})	Notes
2.6444	50.19	0.4635	788024/10413	33.425 ± 0.038	
2.6464	50.12	0.4631	797571/10521	33.911 ± 0.038	
2.7000	48.17	0.4614	22979/317	1.020 ± 0.007	
2.8000	44.81	0.4618	20968/251	1.001 ± 0.007	
2.9000	41.77	0.4618	2057046/26966	105.240 ± 0.074	
2.9500	40.34	0.4622	300499/3904	15.906 ± 0.029	
2.9810	39.52	0.4616	295844/3809	16.011 ± 0.030	
3.0000	39.02	0.4618	287861/3657	15.773 ± 0.030	
3.0200	38.51	0.4620	310240/4189	17.203 ± 0.030	
3.0800	37.02	0.4623	2065095/27005	119.081 ± 0.083	

Comparison between different processes(boss665p01)

Ecm (GeV)	$e^+e^- \to e^+e^-$	$e^+e^- \to \gamma\gamma$	δ (%)
2.0000	10.054	10.134	-0.8
2.0500	3.337	3.350	-0.4
2.1000	12.183	12.137	0.4
2.1500	2.840	2.854	-0.5
2.1750	10.552	10.561	-0.1
2.2000	13.707	13.602	-0.9
2.2324	11.877	11.836	0.3
2.3094	20.782	20.745	0.2
2.3864	22.584	22.537	0.2
2.3960	66.903	66.854	0.1
2.5000	1.096	1.095	0.1
2.6444	33.634	33.425	0.6
2.6464	34.047	33.911	0.4
2.7000	1.033	1.020	1.3
2.8000	1.008	1.001	0.7
2.9000	105.458	105.240	0.2
2.9500	15.905	15.906	0.0
2.9810	16.139	16.011	0.8
3.0000	15.932	15.773	1.0
3.0200	17.306	17.203	0.6
3.0800	120.558	119.081	1.2

Comparison between different boss version

e+e-→e+e-

Ecm (GeV)	665p01	665	δ (%)
2.0000	10.054	10.052	~0
2.0500	3.337	3.356	-0.6
2.1000	12.183	12.096	0.7
2.1500	2.840	2.839	~0
2.1750	10.552	10.625	-0.7
2.2000	13.707	13.657	0.4
2.2324	11.877	11.936	-0.5
2.3094	20.782	21.035	-1.2
2.3864	22.584	22.693	-0.5
2.3960	66.903	67.022	-0.2
2.5000	1.096	1.100	-0.4
2.6440	33.634	33.730	-0.3
2.6464	34.047	34.000	0.1
2.7000	1.033	1.036	-0.3
2.8000	1.008	1.004	0.4
2.9000	105.458	105.225	0.2
2.9500	15.905	16.025	-0.8
2.9810	16.139	16.059	0.5
3.0000	15.932	15.877	0.3
3.0200	17.306	17.333	-0.2
3.0800	120.558	119.398	1.0

Comparison between different boss version

e+e-→γγ

Ecm (GeV)	(665p01)	(665)	δ (%)
2.0000	10.134	10.141	-0.07
2.0500	3.350	3.358	-0.3
2.1000	12.137	12.154	-0.2
2.1500	2.854	2.853	0.04
2.1750	10.561	10.654	-0.9
2.2000	13.602	13.625	-0.2
2.2324	11.836	11.873	-0.3
2.3094	20.745	21.042	-1.4
2.3864	22.537	22.524	0.06
2.3960	66.854	66.827	0.04
2.5000	1.095	1.095	~0
2.6440	33.425	33.449	-0.07
2.6464	33.911	33.883	0.09
2.7000	1.020	1.019	0.1
2.8000	1.001	1.001	0
2.9000	105.240	105.104	0.13
2.9500	15.906	15.914	-0.05
2.9810	16.011	15.993	0.11
3.0000	15.773	15.756	0.11
3.0200	17.203	17.206	-0.02
3.0800	119.081	119.102	-0.02

discuss

- Ecm determination (after calibration)
- cross section determination
- MC production (re-generated)