Dark photon search using $B \to KA'A'$, $A' \to l^+l^-$ decay at Belle

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BELLE

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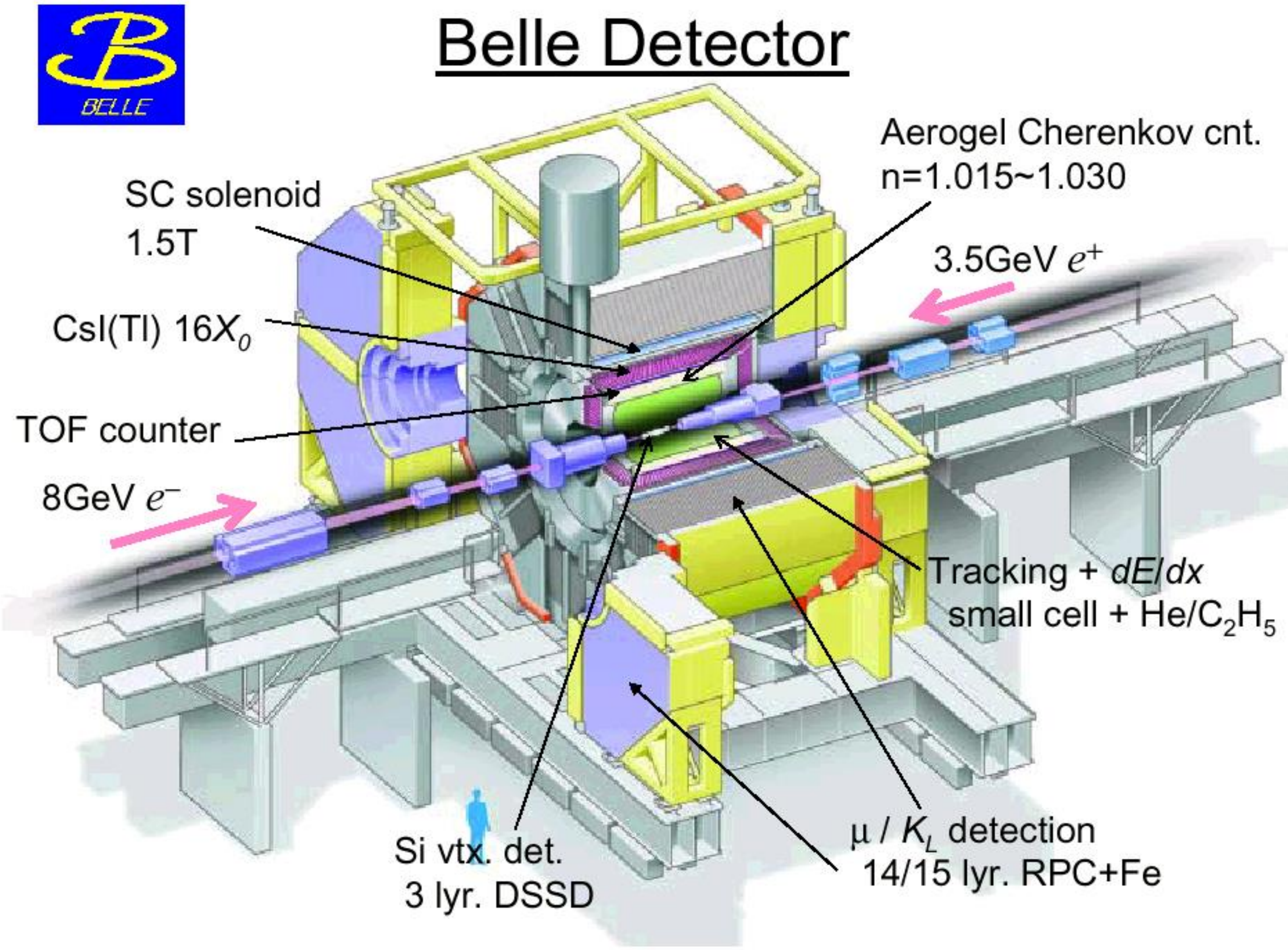
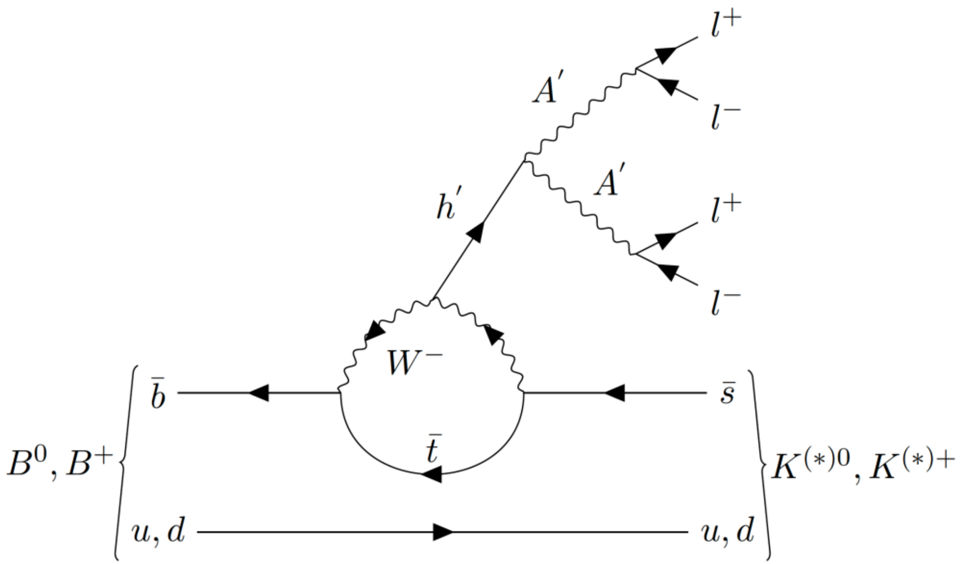
Belle Detector



Electron : 8 GeV
Positron : 3.5 GeV

On $\Upsilon(4S) = 10.58\,\mathrm{GeV}$ resonance mostly decay to $B\bar{B}$ pair

Theoretical Background



Multilepton signature of a hidden sect
or in rare B decays.
Phys. Rev. D 83,054005, B. Batell. et al.

Final States			
$B^+ \to K^+e^+e^-e^+e^+$	$B^0 \to K^0e^+e^-e^+e^+$	$B^+ \to K^{*+}e^+e^-e^+e^+$	$B^0 \to K^{*0}e^+e^-e^+e^+$
$B^+ \to K^+e^+e^-\mu^+\mu^+$	$B^0 \to K^0e^+e^-\mu^+\mu^+$	$B^+ \to K^{*+}e^+e^-\mu^+\mu^+$	$B^0 \to K^{*0}e^+e^-\mu^+\mu^+$
$B^+ \to K^+\mu^+\mu^-\mu^+\mu^+$	$B^0 \to K^0\mu^+\mu^-\mu^+\mu^+$	$B^+ \to K^{*+}\mu^+\mu^-\mu^+\mu^+$	$B^0 \to K^{*0}\mu^+\mu^-\mu^+\mu^+$

Event Generation

- For Signal MC, for each final state decay and A' masses, 1M event generated.
- For A' masses, we generate 0.3 GeV ~1.8 GeV region with 0.1 GeV gap.
- Using EVTGEN and GEANT3
- PHSP used for $B \rightarrow KA'A'$, PHOTOS additionally added to $A' \rightarrow l\bar{l}$
- For Background MC, 10 streams of $B\bar{B}$, 6 streams of $continuum$, 50 streams of $rareB$ and 20 streams of ulv was used to estimate backgrounds. Each stream corresponds to 772M $B\bar{B}$ pairs.

Particle selection

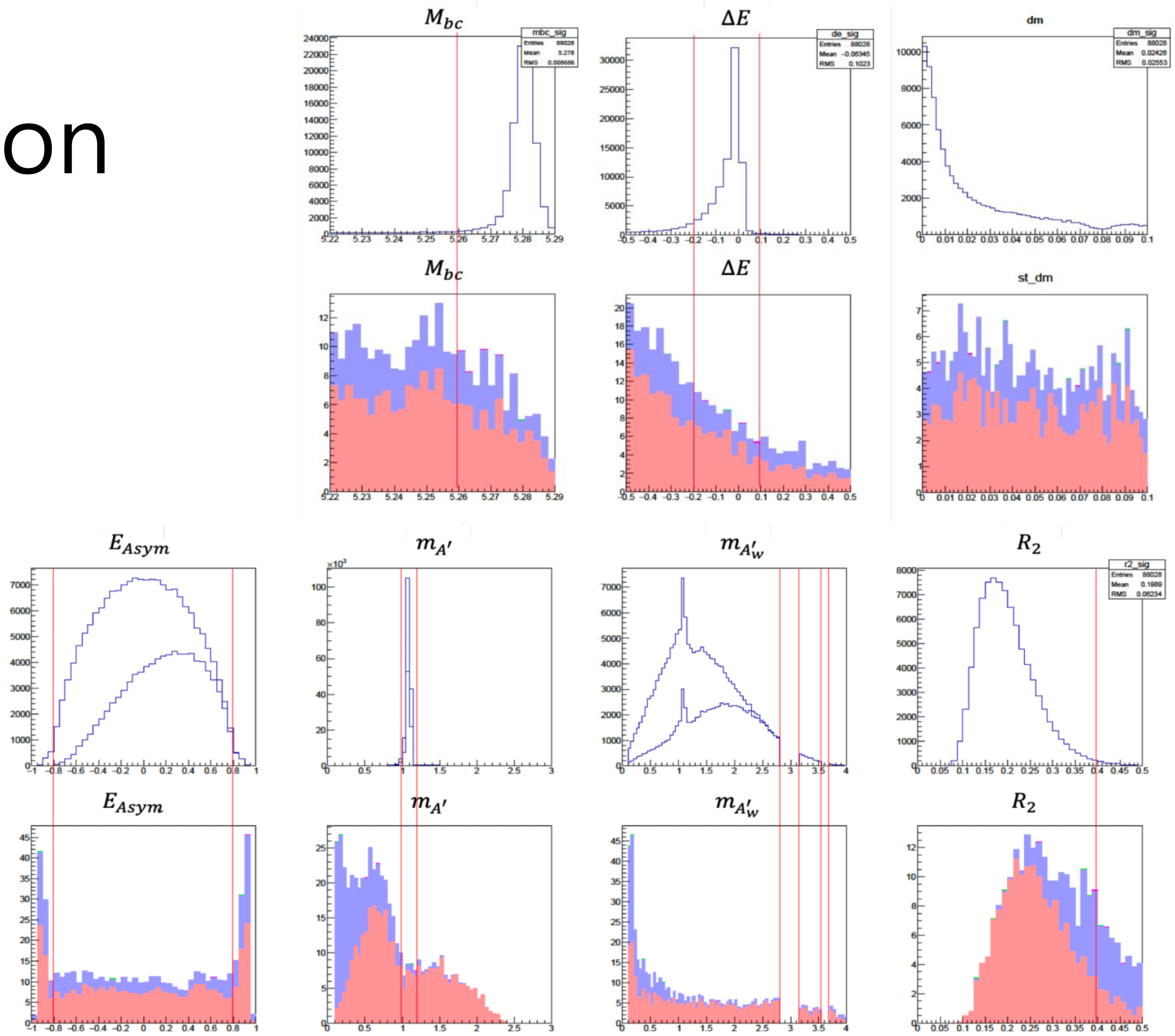
- $dr < 2\ \mathrm{cm},\ dz < 5\ \mathrm{cm}$
- $e^{\pm}$: $\mathcal{L}_e > 0.9,\ \mathcal{L}_e > \mathcal{L}_\mu$, Bremstrahlung-$\gamma$ recon $\angle_e^{\gamma} < 0.05\ \mathrm{rad}$
- $\mu^{\pm}$: $\mathcal{L}_\mu > 0.9,\ \mathcal{L}_e < \mathcal{L}_\mu$
- $K^{\pm}$: $\mathcal{L}_{K/\pi} > 0.6,\ \mathcal{L}_{P/K} < 0.4$
- $\pi^{\pm}$: $\mathcal{L}_{K/\pi} < 0.4,\ \mathcal{L}_{P/\pi} < 0.4$
- γ : Endcap : 150 MeV Barrel : 50 MeV
- K_S^0 : $nisksfinder$ standard cut.
- π^0 : $0.1 < M_\pi < 0.14\ (\mathrm{GeV}),\ P_\pi > 0.1\ \mathrm{GeV}$

Particle Selection cont'd

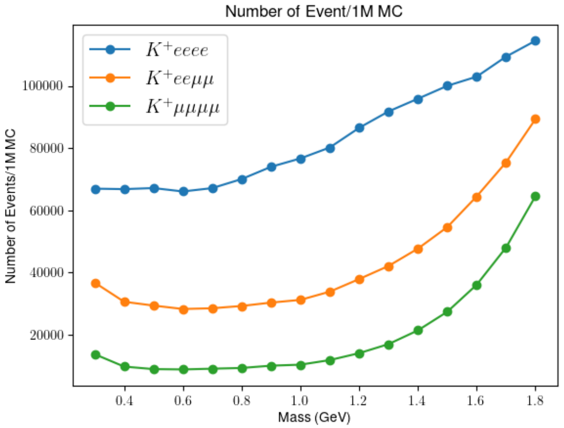
- K^{*+} : $K^{*+} \rightarrow K_S^0\pi^+, K^+\pi^0$, $0.8 < M_{K^{*+}} < 1.0$ (GeV)
- K^{*0} : $K^{*0} \rightarrow K_S^0\pi^0, K^+\pi^-$, $0.8 < M_{K^{*0}} < 1.0$ (GeV)
- A' : $A' \rightarrow e^+e^-, \mu^+\mu^-$, $\Delta M_{A'} < 0.1$ GeV
- Best A' pair selection based on least $\Delta M_{A'}$
- When we select $A' \rightarrow l_{1,3}l_{2,4}$, we call $A'_W \rightarrow l_{1,2}l_{4,3}$
- Best B selection based on least $|\Delta E|$.

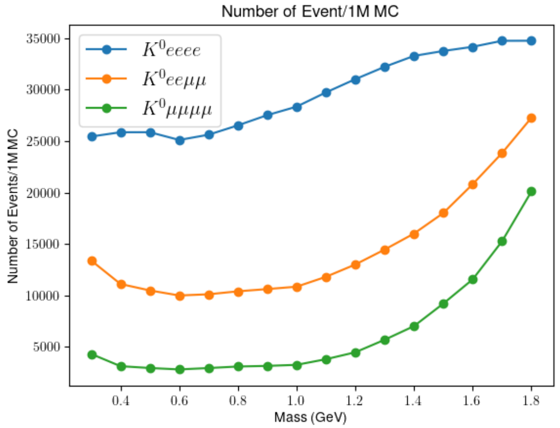
Signal Extraction

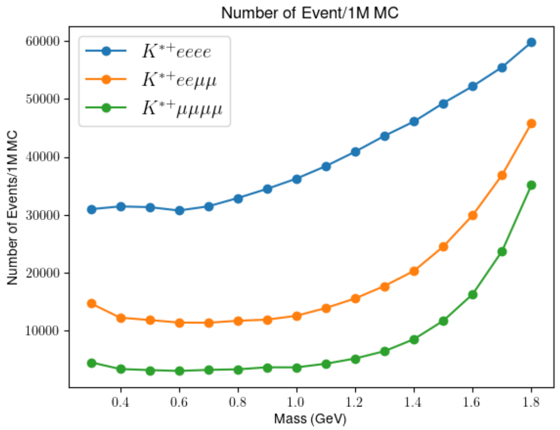
Cuts
$M_{BC} > 5.26$
$-0.2 < \Delta E < 0.1$
$\Delta M_{A'}$: 95% of signal cut
$\lvert E_{Asym} \rvert < 0.8$
$\lvert M_{A'} - \overline{M_{A'}} \rvert < 0.1$ $M_{A'} > 0.1$
$M_{l_{1,2}l_{4,3}} > 0.1$ Veto J/ψ,ϕ on $M_{l_{1,2}l_{4,3}}$
$R_2 < 0.4$

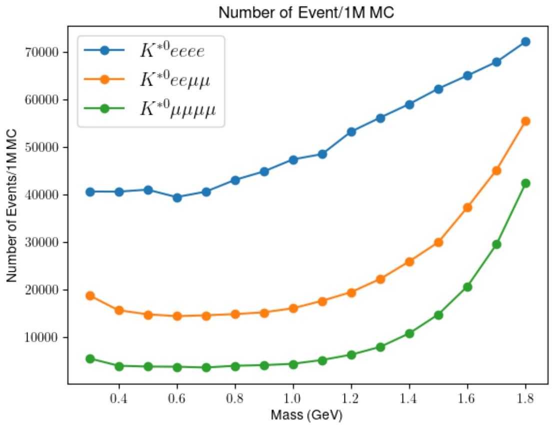


Number of event/1M MC vs Dark photon masses in SignalMC







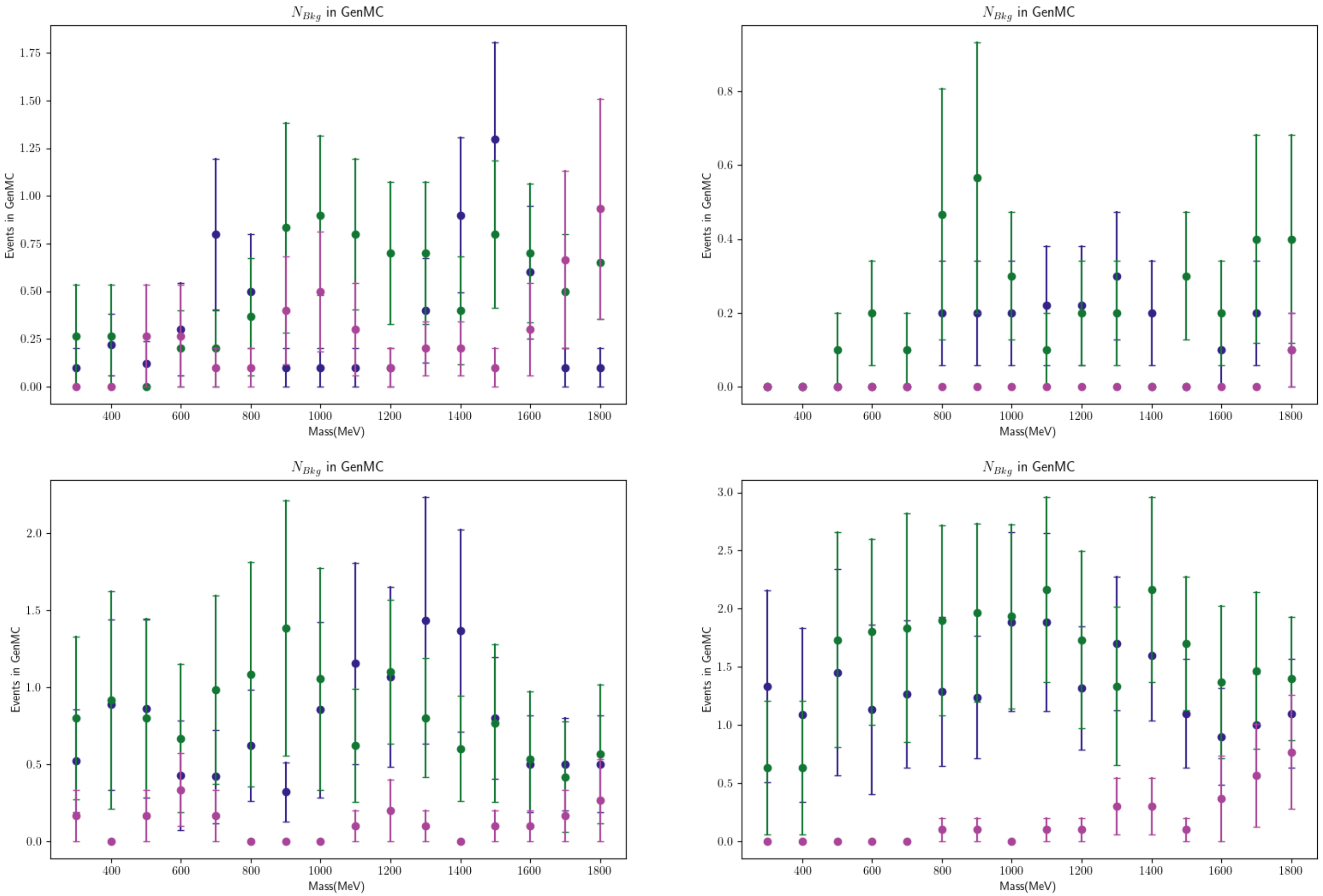


Efficiency tend to increase as M ass increases.
Minimum around 0.6 GeV

Possible for more higher mass r egion and 0.2 GeV for 4 electron subdecay mode.
(Currently 0.3 GeV ~ 1.8 GeV)

K^+ K^0 $eeee$
K^{*+} K^{*0} $ee\mu\mu$
$\mu\mu\mu\mu$

Number of event/1stream vs Dark photon masses in GenMC



This is number of background and its statistical error.

Most of case they are in $O(1)$, 4μ decay have least backgrounds.

K^+	K^0	$eeee$
K^{*+}	K^{*0}	$ee\mu\mu$
		$\mu\mu\mu\mu$

N_{BKG} and its statistical error

Final State	$m_{A'}$	N_{Bkg}	σ_{Bkg}	Final State	$m_{A'}$	N_{Bkg}	σ_{Bkg}
$B^+ \to K^+e^+e^-e^+e^-$	1.1	0.30	0.17	$B^0 \to K^0e^+e^-e^+e^-$	1.1	0.32	0.19
$B^+ \to K^+e^+e^-\mu^+\mu^-$	1.1	1.20	0.35	$B^0 \to K^0e^+e^-\mu^+\mu^-$	1.1	0.10	0.10
$B^+ \to K^+\mu^+\mu^-\mu^+\mu^-$	1.1	0.30	0.17	$B^0 \to K^0\mu^+\mu^-\mu^+\mu^-$	1.1	0.00	0.00
$B^+ \to K^{*+}e^+e^-e^+e^-$	1.1	2.87	0.80	$B^0 \to K^{*0}e^+e^-e^+e^-$	1.1	2.12	0.71
$B^+ \to K^{*+}e^+e^-\mu^+\mu^-$	1.1	3.67	0.88	$B^0 \to K^{*0}e^+e^-\mu^+\mu^-$	1.1	1.92	0.46
$B^+ \to K^{*+}\mu^+\mu^-\mu^+\mu^-$	1.1	0.87	0.43	$B^0 \to K^{*0}\mu^+\mu^-\mu^+\mu^-$	1.1	0.40	0.20

After cut, in most of mass region, $N_{BKG} \sim O(1)$, E.U.L of B.F $O(10^{-8}) \sim O(10^{-6})$

Control Sample Study

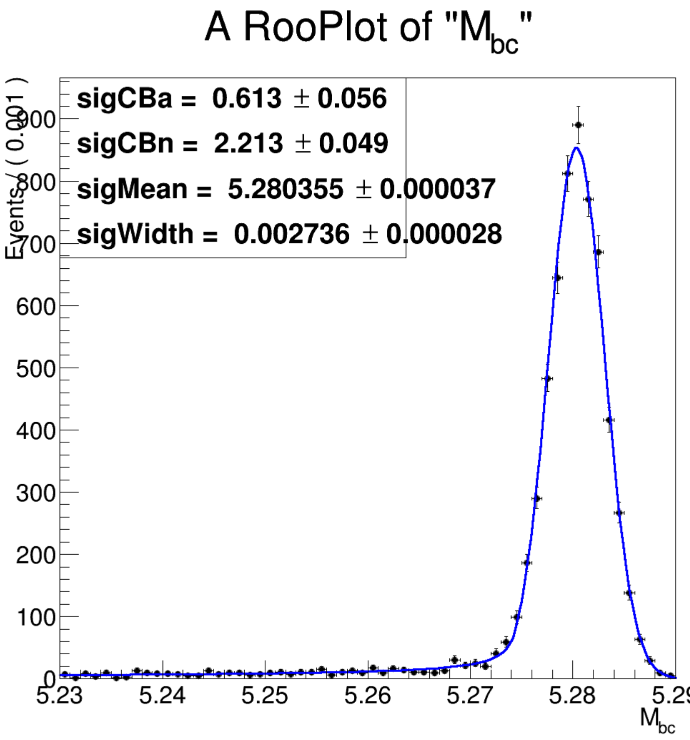
- To validate R_2 cut.

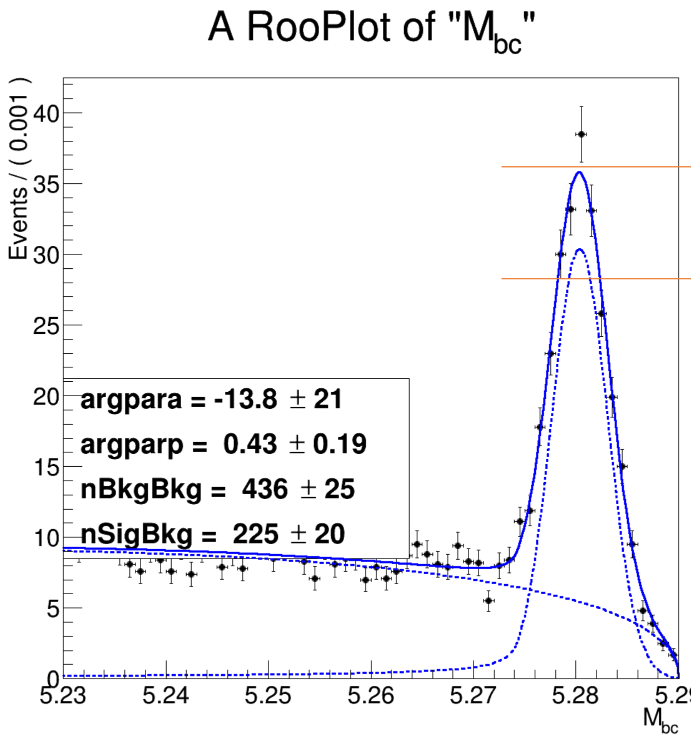
- Control sample study using $B \to D\bar{D}K$ was not successful
  - So many resonant state inside it.

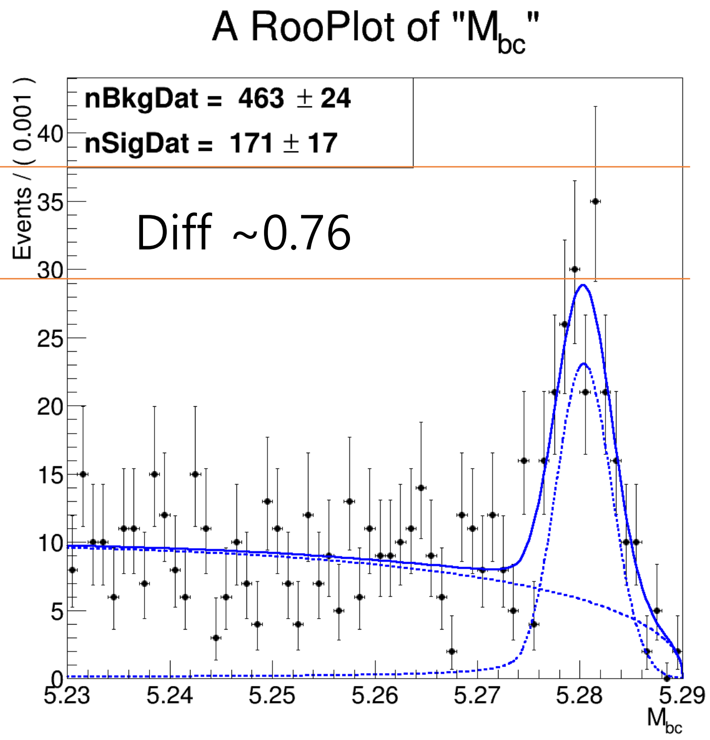
- Control sample study now uses $B^+ \to J/\psi\phi K^+$, $J/\psi \to l^+l^-$, $\phi \to K^+K^-$
  - Modified M_{BC} was used to solve peak shift. $M_{BC} = M_{BC} - E_{beam} + 5.29$
  - Data/MC comparing result was consistent with our expectation.
  - Fitting was used.

Control sample study
Signal fit. SigMC/GenMC/Data

Cuts	notes
$M_{BC} > 5.22\,GeV$	
$-0.05 < \Delta E < 0.05$	
$3.0 < M_{J\psi} < 3.2$	
$0.97 < M_{\phi} < 1.07$	
$\lvert (M_{J\psi} - M_{\phi}) - (3.1 - 1.020) \rvert < 0.0701$	determined by 95% cut
$M_{(l,K)_i(l,K)_j} > 0.1$	
$R_2 < 0.4$	







CB

CB from SigMC + Argus

Control sample study result

$R_{PID,/wR_2}$	0.9585 ± 0.0392	$R_{PID,/woR_2}$	0.9578 ± 0.0394
$N_{Sig,MC,/wR_2}$ $N_{Sig,MC,/wR_2} \times R_{trk}$	225.3 ± 6.5 $216.0 \pm 6.2 \pm 8.8$	$N_{Sig,MC./woR_2}$ $N_{Sig,MC./woR_2} \times R_{trk}$	240.6 ± 6.7 $230.4 \pm 6.4 \pm 9.5$
$N_{Sig,Data,/wR_2}$	171 ± 17	$N_{Sig,Data,/woR_2}$	178 ± 17
$\frac{N_{Sig,MC,/wR_2}}{N_{Sig,MC,/woR_2}}$	$0.9371 \pm 0.030 \pm 0.002$	$\frac{N_{Sig,DATA,/wR_2}}{N_{Sig,DATA,/woR_2}}$	0.9607 ± 0.093
$\frac{N_{Sig,Data,/wR_2}/N_{Sig,Data,/woR_2}}{N_{Sig,MC,/wR_2}/N_{Sig,MC,/woR_2}}$	$1.025 \pm 0.100 \pm 0.002$	$\frac{N_{Sig,Data,/wR_2}}{N_{Sig,MC,/wR_2}}$	0.7590 ± 0.1035

Comparison between $R_2 < 0.4$ cut and No R_2 cut. In compare to Data and MC they have almost same.

Control sample study result

	BF	Notes
BF_{PDG}	$(5.0 \pm 0.4) \times 10^{-5}$	BABR/CLE2
BF_{MC}	$(5.2) \times 10^{-5}$	DECAY.DEC
BF_{MC}	$(4.36 \pm 0.15 \pm 0.18) \times 10^{-5}$	
BF_{DATA}	$(4.36 \pm 0.44 \pm 0.18) \times 10^{-5}$	
$\frac{BF_{DATA}}{BF_{PDG}}$	(0.87 ± 0.12)	slight bigger than 1 σ from 1
$\frac{BF_{DATA}}{BF_{MC}}$	$(1.00 \pm 0.11 \pm 0.04)$	

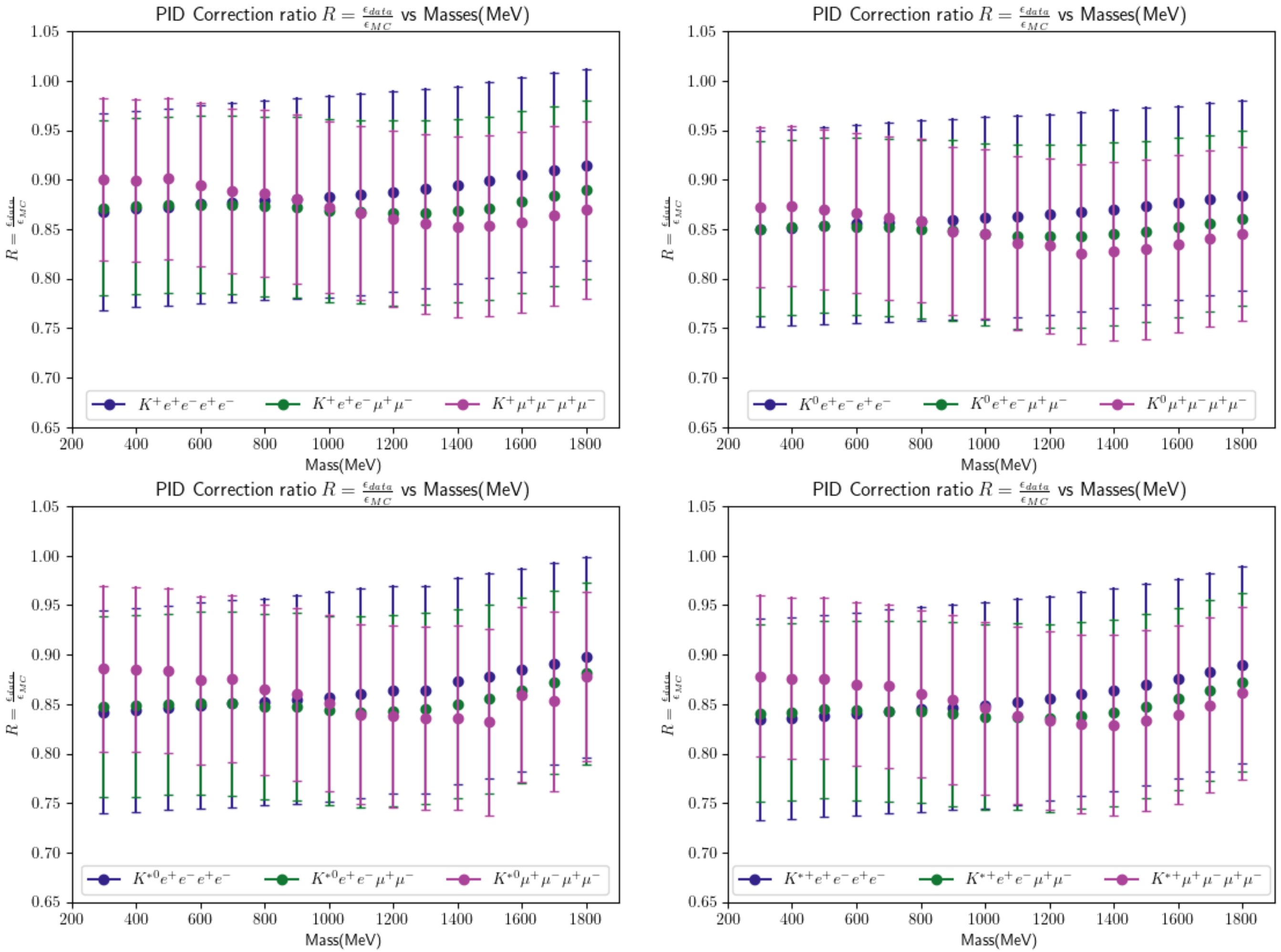
Difference between Data and MC are consistent with expected result.
Slight lower than PDG value.

Systematic study

- PID Correction is main source of systematic error.

- Systematics for tracking is relatively low (~0.7% in total) in compared to PID correction (~10%)

PID Correction ratio R vs Masses



R is around 0.85,
and its error is around 10%.

The more muon event have less error.

K^+ K^0
K^{*0} K^{*+}

$eeee$
$ee\mu\mu$
$\mu\mu\mu\mu$

Expected Upper Limit of Branching Fraction using MC w.r.t $m_{A'}, N_{Obs}$ (10^{-6})

Kpluseeee	0	1	2	3	4	5
300	0.053908	0.1005	0.13488	0.17526	0.20987	0.24248
400	0.052318	0.096877	0.13212	0.16937	0.20705	0.23964
500	0.053257	0.099251	0.13336	0.17275	0.20775	0.2401
600	0.051744	0.094567	0.13114	0.16728	0.20653	0.23932
700	0.038764	0.077309	0.11782	0.15067	0.18659	0.22404
800	0.045028	0.082517	0.11896	0.15037	0.18975	0.22053
900	0.048086	0.089642	0.12031	0.15633	0.1872	0.21629
1000	0.046301	0.086314	0.11585	0.15053	0.18025	0.20826
1100	0.044174	0.082349	0.11053	0.14361	0.17197	0.19869
1200	0.040818	0.076093	0.10213	0.1327	0.15891	0.1836
1300	0.035659	0.064376	0.091199	0.11566	0.14453	0.16772
1400	0.024822	0.051149	0.079432	0.102	0.12532	0.15239
1500	0.020235	0.043054	0.070178	0.091562	0.1128	0.13476
1600	0.027991	0.052656	0.077321	0.098106	0.12416	0.14453
1700	0.031521	0.058761	0.078866	0.10247	0.12271	0.14178
1800	0.029964	0.055858	0.074971	0.097413	0.11665	0.13478

Kpluseemm	0	1	2	3	4	5
300	0.094063	0.17245	0.23757	0.3039	0.37344	0.43253
400	0.11267	0.20656	0.28456	0.364	0.4473	0.51808
500	0.12476	0.23198	0.30964	0.40434	0.47899	0.55264
600	0.12324	0.22879	0.31095	0.39935	0.48671	0.56315
700	0.12234	0.22713	0.30869	0.39644	0.48316	0.55905
800	0.1149	0.20813	0.2928	0.37192	0.46313	0.53721
900	0.084142	0.16974	0.26021	0.33268	0.41147	0.4961
1000	0.078344	0.16144	0.2507	0.32192	0.39552	0.48099
1100	0.077615	0.15479	0.23592	0.30169	0.37361	0.44859
1200	0.074128	0.14394	0.21493	0.27376	0.34279	0.40516
1300	0.066709	0.12954	0.19342	0.24637	0.30849	0.36461
1400	0.070283	0.12688	0.17975	0.22795	0.28486	0.33058
1500	0.047935	0.0956	0.1457	0.18633	0.23074	0.27705
1600	0.043055	0.083605	0.12484	0.15901	0.1991	0.23532
1700	0.041599	0.076232	0.1099	0.13892	0.17529	0.20374
1800	0.031814	0.060545	0.089762	0.11411	0.14414	0.16849

Kplusmmmm	0	1	2	3	4	5
300	0.25827	0.48025	0.64102	0.83706	0.99161	1.1441
400	0.36312	0.6752	0.90124	1.1769	1.3942	1.6085
500	0.37111	0.68038	0.9373	1.199	1.4734	1.7065
600	0.37809	0.69316	0.95491	1.2215	1.501	1.7386
700	0.38526	0.7182	0.96394	1.2525	1.4998	1.7329
800	0.37667	0.70218	0.94245	1.2246	1.4664	1.6942
900	0.32715	0.59061	0.8367	1.0611	1.326	1.5388
1000	0.30426	0.55757	0.8038	1.0161	1.2821	1.4901
1100	0.28979	0.52961	0.73446	0.93681	1.1566	1.3403
1200	0.25747	0.47998	0.64421	0.83705	1.0023	1.1581
1300	0.20948	0.38891	0.52856	0.67882	0.82731	0.95725
1400	0.16702	0.31008	0.42143	0.54124	0.65963	0.76323
1500	0.13374	0.24932	0.33462	0.43479	0.52065	0.60155
1600	0.096624	0.17659	0.24489	0.31236	0.38566	0.44688
1700	0.060336	0.11539	0.17137	0.21802	0.27462	0.32221
1800	0.036988	0.077192	0.12061	0.15484	0.18999	0.23204

They are in $O(10^{-6})$~$O(10^{-8})$

Summary

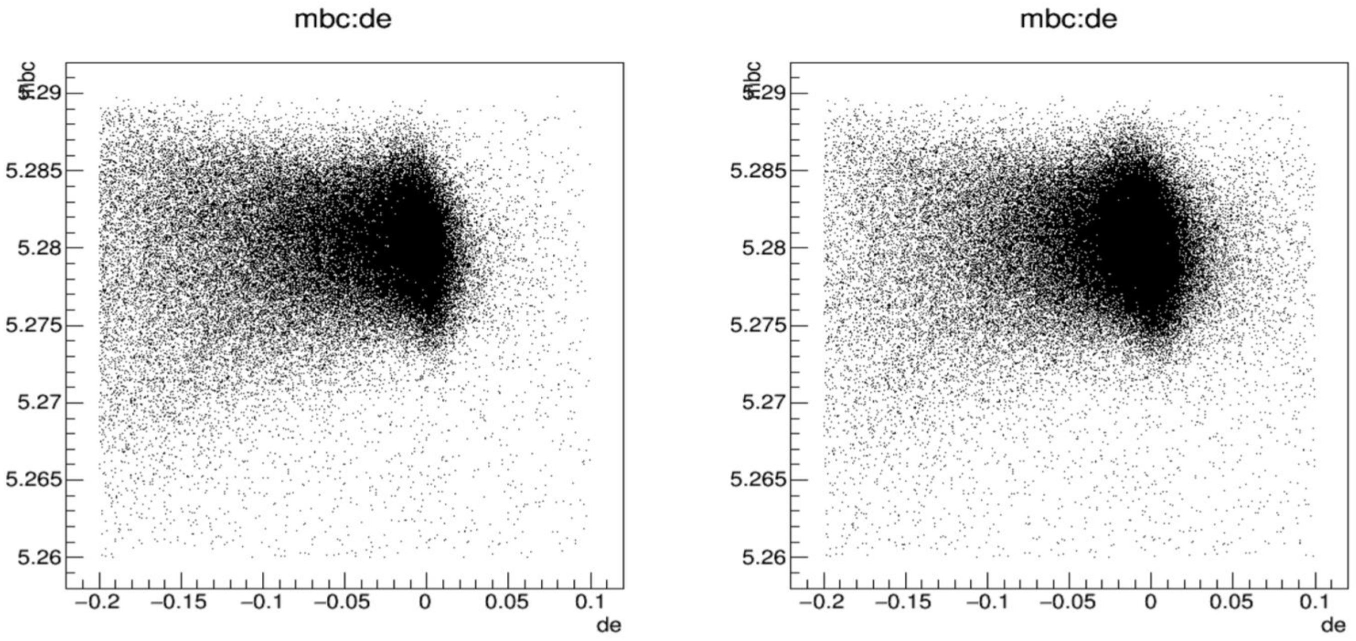
- Controlsample study using $B^+ \to J/\psi\phi K^+$ is consistent with o ur expectation.
- Systematic study was done. Main source of systematic error was PID correction.
- Expected upper limit of Branching fraction is estimated

Backup

Particle selection cont'd

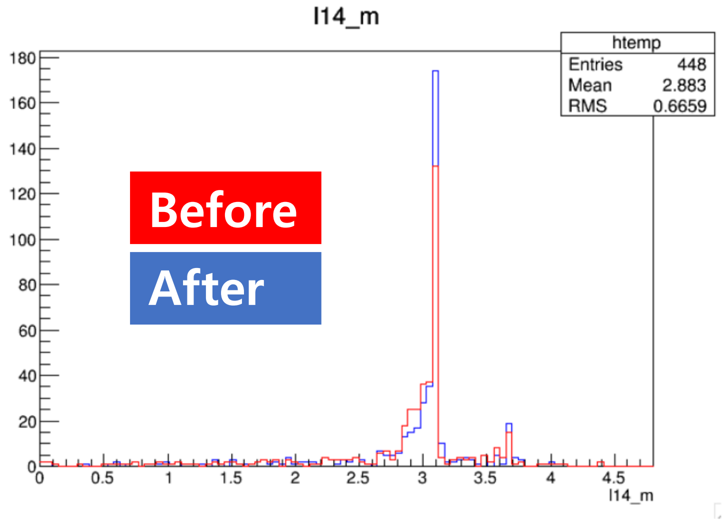
- Least $\Delta M_{A'}$ for A' pair selection.
- Least $|\Delta E|$ for best B selection.

Bremsstrahlung reconstruction



$M_{bc}\ vs\ \Delta E$ before, after bremsstrahlung reconstruction

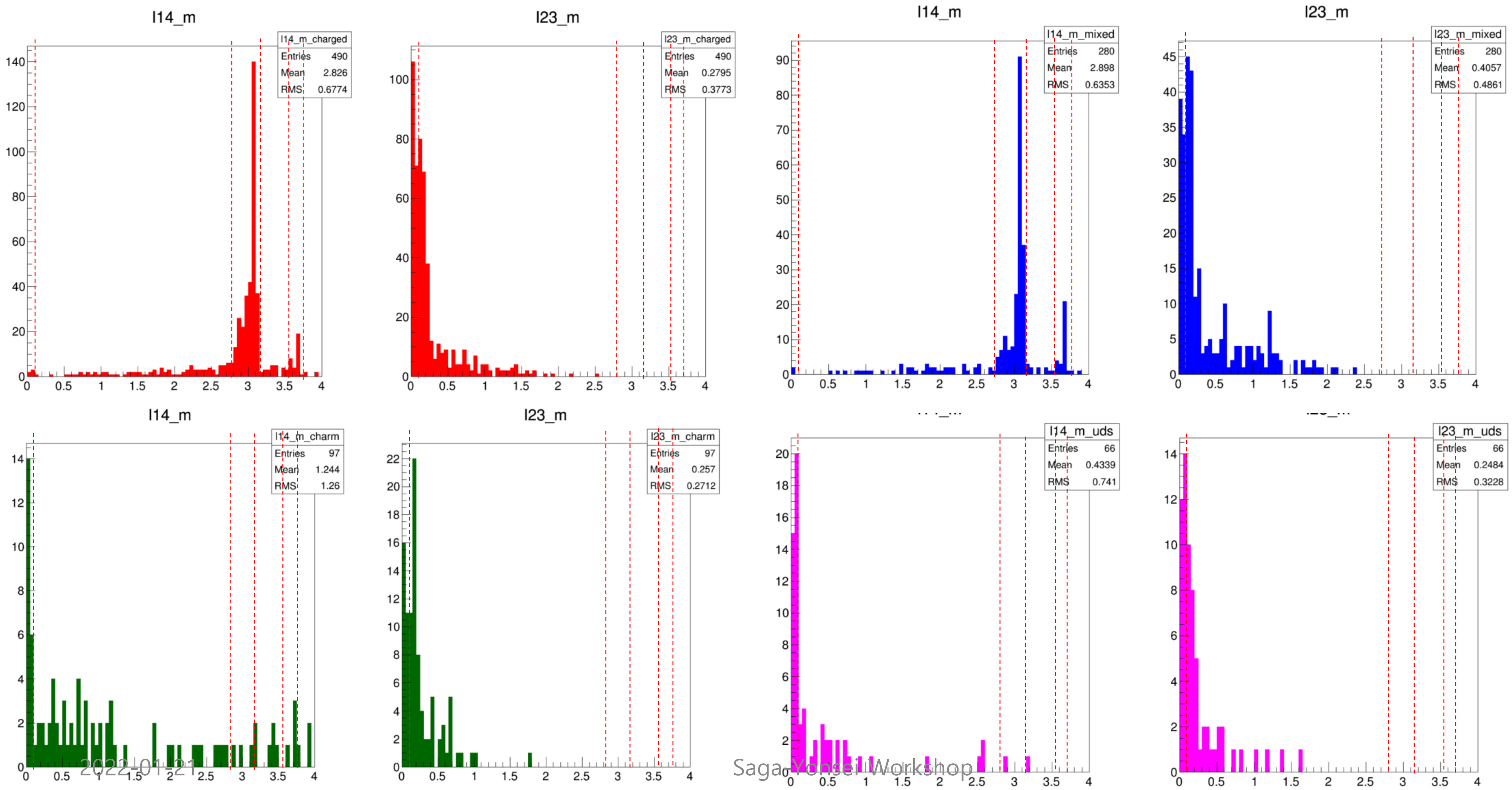
$\angle_e^{\gamma} < 0.05\ rad$ used bremsstrahlung reconstruction.
Electron containing mode have Bremsstrahlung reconstruction process



Effect on J/ψ, $\psi(2S)$ background veto

Low mass/cc veto

J/ψ veto : $2.8 < m_{A'_w} < 3.15$ GeV
$\psi(2S)$ veto : $3.55 < m_{A'_w} < 3.7$ GeV
Low mass veto
$m_{A'} < 0.1$ GeV, $m_{A'} < 0.1$ GeV



Charged
Mixed
Charm
Uds

$\Delta m_{A'}$ cut determination

Background is almost flat.
Figure of merit punzi fluctuates hard due to lack of background. ($O(1)$)
Signal 95% cut applied to some points,
And interpolated it with dark photon mass

Final States	0.6 GeV	1.1 GeV	1.6 GeV	Final States	0.6 GeV	1.1 GeV	1.6 GeV
$K^0e^+e^-e^+e^-$	0.062	0.068	0.078	$K^+e^+e^-e^+e^-$	0.060	0.068	0.080
$K^0e^+e^-\mu^+\mu^-$	0.056	0.064	0.074	$K^+e^+e^-\mu^+\mu^-$	0.054	0.062	0.074
$K^0\mu^+\mu^-\mu^+\mu^-$	0.016	0.020	0.030	$K^+\mu^+\mu^-\mu^+\mu^-$	0.014	0.020	0.030
$K^{*0}e^+e^-e^+e^-$	0.062	0.068	0.078	$K^{*+}e^+e^-e^+e^-$	0.064	0.068	0.078
$K^{*0}e^+e^-\mu^+\mu^-$	0.058	0.064	0.076	$K^{*+}e^+e^-\mu^+\mu^-$	0.056	0.062	0.072
$K^{*0}\mu^+\mu^-\mu^+\mu^-$	0.016	0.024	0.030	$K^{*+}\mu^+\mu^-\mu^+\mu^-$	0.020	0.028	0.030

PID Correction

	Mass (GeV)	K^+		K^0		K^{*+}		K^{*0}	
		R	σ_R	R	σ_R	R	σ_R	R	σ_R
$e^+e^-e^+e^-$	0.6	0.8751	0.1004	0.8553	0.1004	0.8402	0.1026	0.8483	0.1041
	1.1	0.8849	0.1021	0.8628	0.1018	0.8519	0.1042	0.8609	0.1059
	1.6	0.9049	0.0983	0.8765	0.0978	0.8757	0.1009	0.8844	0.1024
$e^+e^-\mu^+\mu^-$	0.6	0.8750	0.0896	0.8526	0.0895	0.8434	0.0908	0.8509	0.0925
	1.1	0.8673	0.0928	0.8427	0.0931	0.8375	0.0943	0.8422	0.0965
	1.6	0.8777	0.0918	0.8520	0.0906	0.8553	0.0918	0.8637	0.0935
$\mu^+\mu^-\mu^+\mu^-$	0.6	0.8949	0.0825	0.8663	0.0811	0.8699	0.0824	0.8741	0.0848
	1.1	0.8661	0.0881	0.8357	0.0882	0.8385	0.0892	0.8396	0.0906
	1.6	0.8568	0.0912	0.8352	0.0895	0.8395	0.0901	0.8596	0.0881

Table. PID correction ratio($R = \frac{\epsilon_{DATA}}{\epsilon_{MC}}$) and its uncertainty

K0eeee	0	1	2	3	4	5
300	0.15686	0.29167	0.38932	0.50838	0.60224	0.69485
400	0.1541	0.28653	0.38246	0.49942	0.59163	0.68261
500	0.1537	0.2858	0.38147	0.49814	0.59011	0.68085
600	0.158	0.29379	0.39214	0.51207	0.60661	0.69989
700	0.15462	0.28751	0.38376	0.50112	0.59364	0.68493
800	0.14181	0.26328	0.35783	0.45955	0.56008	0.64804
900	0.13602	0.25253	0.34321	0.44078	0.5372	0.62157
1000	0.13232	0.24565	0.33387	0.42878	0.52258	0.60465
1100	0.12537	0.23215	0.31662	0.40587	0.49618	0.57428
1200	0.11988	0.22198	0.30274	0.38808	0.47443	0.5491
1300	0.11317	0.20682	0.28682	0.36584	0.45169	0.52339
1400	0.11153	0.20706	0.28141	0.36141	0.44047	0.50965
1500	0.1151	0.21403	0.28567	0.37304	0.44192	0.50987
1600	0.11059	0.20615	0.27669	0.35952	0.43051	0.49741
1700	0.10558	0.19602	0.26641	0.34214	0.41699	0.48247
1800	0.1078	0.20095	0.26971	0.35045	0.41965	0.48486

K0eemm	0	1	2	3	4	5
300	0.29801	0.55413	0.73964	0.96583	1.1442	1.3201
400	0.35852	0.66664	0.88981	1.1619	1.3765	1.5881
500	0.37022	0.69017	0.92632	1.2036	1.4413	1.6652
600	0.37915	0.7039	0.95667	1.2286	1.4974	1.7326
700	0.38456	0.7169	0.9622	1.2502	1.4971	1.7297
800	0.33932	0.6154	0.88069	1.1136	1.402	1.6287
900	0.3116	0.58237	0.84859	1.0755	1.3599	1.5822
1000	0.34501	0.63053	0.87441	1.1153	1.377	1.5956
1100	0.3328	0.62041	0.83269	1.082	1.2956	1.4969
1200	0.29479	0.54728	0.74381	0.95526	1.1642	1.3471
1300	0.26509	0.49215	0.66888	0.85903	1.0469	1.2114
1400	0.25071	0.46618	0.62225	0.81255	0.96257	1.1106
1500	0.20709	0.37847	0.52486	0.66946	0.82657	0.95778
1600	0.1821	0.33807	0.45947	0.59009	0.71918	0.83212
1700	0.15096	0.27252	0.38607	0.4896	0.61184	0.71003
1800	0.13116	0.23678	0.33544	0.4254	0.5316	0.61691

K0mmmm	0	1	2	3	4	5
300	0.90272	1.6786	2.2405	2.9257	3.4659	3.9988
400	1.2459	2.3166	3.0922	4.0379	4.7834	5.5189
500	1.326	2.4656	3.291	4.2975	5.0909	5.8737
600	1.3972	2.598	3.4677	4.5282	5.3642	6.1891
700	1.341	2.4936	3.3284	4.3463	5.1488	5.9405
800	1.2805	2.381	3.178	4.15	4.9162	5.6721
900	1.2717	2.3646	3.1562	4.1214	4.8823	5.6331
1000	1.236	2.2982	3.0676	4.0057	4.7453	5.475
1100	1.0696	1.9888	2.6546	3.4664	4.1064	4.7379
1200	0.91116	1.6942	2.2614	2.953	3.4983	4.0362
1300	0.72329	1.3449	1.7952	2.3442	2.777	3.204
1400	0.58428	1.0864	1.4501	1.8936	2.2433	2.5882
1500	0.44415	0.82586	1.1023	1.4395	1.7052	1.9674
1600	0.3514	0.65341	0.87216	1.1389	1.3492	1.5566
1700	0.26452	0.49186	0.65653	0.85731	1.0156	1.1718
1800	0.19496	0.36345	0.48781	0.63383	0.75899	0.87693

Kstarpluseeee	0	1	2	3	4	5
300	0.1058	0.19514	0.28247	0.35734	0.45116	0.52452
400	0.081914	0.16775	0.25947	0.33305	0.41006	0.49737
500	0.083506	0.16996	0.26132	0.33501	0.41311	0.49956
600	0.11186	0.20224	0.28714	0.36354	0.45592	0.52933
700	0.10948	0.19754	0.28026	0.3547	0.44472	0.51624
800	0.09286	0.17504	0.25815	0.3278	0.41508	0.48334
900	0.10166	0.18607	0.259	0.32972	0.40839	0.47336
1000	0.07167	0.14502	0.22339	0.28584	0.3529	0.42667
1100	0.058728	0.12337	0.19826	0.25738	0.31532	0.38233
1200	0.05674	0.1179	0.18864	0.24354	0.29807	0.3666
1300	0.046034	0.099283	0.16318	0.21471	0.26521	0.31571
1400	0.044643	0.095109	0.15593	0.20413	0.25201	0.29988
1500	0.053214	0.10613	0.16175	0.20684	0.25615	0.30756
1600	0.060633	0.11111	0.16018	0.20249	0.2555	0.29696
1700	0.056601	0.10372	0.14953	0.18902	0.23851	0.27721
1800	0.052106	0.095486	0.13766	0.17401	0.21957	0.2552

Kstarpluseemm	0	1	2	3	4	5
300	0.18486	0.36867	0.56189	0.71855	0.88983	1.0684
400	0.20465	0.42437	0.66041	0.84874	1.0421	1.2693
500	0.2292	0.45711	0.69667	0.8909	1.1033	1.3247
600	0.26125	0.49962	0.74202	0.94402	1.1891	1.3952
700	0.21357	0.44607	0.7029	0.9043	1.1071	1.3585
800	0.20089	0.41884	0.66962	0.86526	1.0596	1.2985
900	0.17747	0.37956	0.62181	0.81612	1.0066	1.197
1000	0.18955	0.39633	0.63141	0.81481	0.99697	1.2284
1100	0.22214	0.41873	0.61754	0.78414	0.99295	1.1562
1200	0.15113	0.31518	0.50508	0.65421	0.80136	0.97834
1300	0.15389	0.30692	0.46777	0.59819	0.74078	0.88946
1400	0.15267	0.28719	0.42172	0.53509	0.67717	0.78827
1500	0.11239	0.22229	0.33592	0.42906	0.53338	0.63708
1600	0.10633	0.19602	0.28471	0.3598	0.45453	0.52911
1700	0.091119	0.16442	0.23326	0.29563	0.37015	0.42968
1800	0.066446	0.12418	0.18095	0.22933	0.28997	0.33739

Kstarplusmmmm	0	1	2	3	4	5
300	0.78402	1.4663	1.9715	2.5423	3.0803	3.5625
400	1.1066	2.0576	2.7465	3.5864	4.2486	4.9019
500	1.1244	2.103	2.8276	3.6462	4.4178	5.1094
600	1.1431	2.0823	2.9073	3.6975	4.5822	5.3177
700	1.1211	2.0967	2.819	3.6352	4.4045	5.094
800	1.1448	2.1287	2.8414	3.7103	4.3954	5.0712
900	1.04	1.9338	2.5812	3.3706	3.9929	4.6069
1000	1.0551	1.9618	2.6186	3.4195	4.0508	4.6737
1100	0.88378	1.6475	2.2113	2.8732	3.4406	3.9752
1200	0.71523	1.3278	1.8047	2.3177	2.8247	3.2683
1300	0.58962	1.0992	1.4753	1.9169	2.2954	2.6521
1400	0.45735	0.85041	1.1351	1.4822	1.7559	2.0259
1500	0.32252	0.60123	0.80696	1.0485	1.2556	1.4507
1600	0.22943	0.4277	0.57405	0.74588	0.89317	1.032
1700	0.15311	0.28635	0.38501	0.49647	0.60154	0.69571
1800	0.099706	0.18279	0.25182	0.32213	0.39584	0.45848

Kstar0eeee	0	1	2	3	4	5
300	0.055387	0.11834	0.19326	0.25302	0.3116	0.37177
400	0.060857	0.12688	0.20286	0.26212	0.32099	0.39298
500	0.052225	0.1127	0.18573	0.24463	0.30235	0.36007
600	0.061078	0.12786	0.20563	0.26671	0.32657	0.39701
700	0.056443	0.1196	0.1942	0.25301	0.31142	0.37339
800	0.05275	0.11181	0.18202	0.23737	0.29235	0.34993
900	0.051208	0.10846	0.17567	0.22901	0.28164	0.33818
1000	0.037251	0.085577	0.13558	0.19465	0.24398	0.29331
1100	0.036241	0.083255	0.1319	0.18936	0.23736	0.28535
1200	0.041493	0.088322	0.14434	0.1885	0.23236	0.27741
1300	0.033541	0.074909	0.12075	0.16715	0.20851	0.24932
1400	0.033311	0.072966	0.11844	0.16074	0.19986	0.23846
1500	0.037883	0.079007	0.12661	0.16399	0.20088	0.24524
1600	0.039111	0.080592	0.12515	0.16071	0.19745	0.24012
1700	0.035393	0.073943	0.11678	0.15059	0.18396	0.22611
1800	0.032007	0.066751	0.10697	0.13855	0.16972	0.2072

Kstar0eemm	0	1	2	3	4	5
300	0.16942	0.32088	0.4749	0.60239	0.76326	0.8899
400	0.20315	0.38475	0.56943	0.72231	0.9152	1.067
500	0.12898	0.28832	0.46174	0.64492	0.80534	0.96359
600	0.12903	0.29032	0.46385	0.65406	0.81868	0.9822
700	0.12525	0.28346	0.45156	0.64274	0.80425	0.96575
800	0.12038	0.27547	0.43598	0.62795	0.78737	0.9468
900	0.11318	0.26337	0.41568	0.60501	0.7605	0.91598
1000	0.10961	0.25241	0.40024	0.57824	0.72707	0.87389
1100	0.08994	0.21567	0.3359	0.5066	0.64243	0.77642
1200	0.098842	0.22094	0.35384	0.49421	0.61714	0.73841
1300	0.10077	0.21531	0.35159	0.46033	0.5669	0.67637
1400	0.060575	0.14526	0.22623	0.3412	0.43268	0.52292
1500	0.063762	0.1424	0.22954	0.31775	0.39639	0.47396
1600	0.058327	0.12426	0.20372	0.2667	0.32925	0.3918
1700	0.045647	0.098901	0.16322	0.21475	0.26593	0.31676
1800	0.03792	0.081137	0.13356	0.1751	0.21637	0.25707

Kstar0mmmm	0	1	2	3	4	5
300	0.69305	1.2887	1.7201	2.2462	2.6609	3.07
400	0.96409	1.7927	2.3928	3.1246	3.7015	4.2706
500	1.0111	1.8801	2.5094	3.2769	3.8819	4.4788
600	1.0296	1.9145	2.5555	3.337	3.9531	4.561
700	1.0772	2.003	2.6736	3.4913	4.1359	4.7718
800	0.9652	1.7993	2.415	3.1379	3.7575	4.3414
900	0.93979	1.7519	2.3514	3.0553	3.6586	4.2271
1000	0.90949	1.6911	2.2573	2.9476	3.4919	4.0288
1100	0.76141	1.4194	1.9051	2.4754	2.9642	3.4248
1200	0.62719	1.1692	1.5693	2.039	2.4417	2.8211
1300	0.45699	0.83519	1.1582	1.4773	1.824	2.1136
1400	0.37279	0.6813	0.94483	1.2051	1.4879	1.7241
1500	0.66884	1.2468	1.6735	2.1744	2.6038	3.0084
1600	0.49824	0.90252	1.2696	1.6127	2.0083	2.3295
1700	0.3706	0.69263	1.0093	1.2791	1.6173	1.8818
1800	0.13165	0.26039	0.3935	0.5026	0.62479	0.74626