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CEPC

Measurement of $B^0/B_s \rightarrow \pi^0\pi^0$ at CEPC

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2021.01.13

CEPC Physics and Detector Plenary meeting

Outline

- Brief introduction of B^0 & Bs → $\pi^o\pi^o$
- Reconstruction of π^o
- Separation of B^0 and Bs
- Individual measurement of B^0/Bs → $\pi^o\pi^o$
- Mixed measurement of B^0/Bs → $\pi^o\pi^o$
- Summary

Brief introduction of B^0 & Bs → $\pi^o\pi^o$

$B^0 \to \pi^o\pi^o$

$\Gamma(\pi^0\pi^0)/\Gamma_{total}$ **in PDG 2018** Γ_{388}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
1.59±0.26 OUR AVERAGE		Error includes scale factor of 1.4.			
1.31±0.19±0.19		[1] JULIUS	17	BELL	$e^+e^- \to \Upsilon(4S)$
1.83±0.21±0.13		[1] LEES	13D	BABR	$e^+e^- \to \Upsilon(4S)$

(2017) https://journals.aps.org/prd/abstract/10.1103/PhysRevD.96.032007

Bs → $\pi^o\pi^o$

Experimental upper limit

$\Gamma(\pi^0\pi^0)/\Gamma_{total}$ **in PDG 2018** Γ_{87}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<2.1 \times 10^{-4}$	90	[1] ACCIARRI	95H	L3	$e^+e^- \to Z$

[1] ACCIARRI 95H assumes $f_{B^0} = 39.5 \pm 4.0$ and $f_{B_s} = 12.0 \pm 3.0\%$.

(1995) https://www.sciencedirect.com/science/article/pii/037026939501042O

Theoretical estimation

$\bar{B}^0_s \to \pi^+\pi^-$	ann	$0.024^{+0.003+0.025+0.000+0.163}_{-0.003-0.012-0.000-0.021}$	···	$0.57^{+0.16+0.09+0.01}_{-0.13-0.10-0.00}$	<1.36
$\bar{B}^0_s \to \pi^0\pi^0$	ann	$0.012^{+0.001+0.013+0.000+0.082}_{-0.001-0.006-0.000-0.011}$	···	$0.28^{+0.08+0.04+0.01}_{-0.07-0.05-0.00}$	<210

(2007) https://journals.aps.org/prd/abstract/10.1103/PhysRevD.76.074018

~ 3×10^{-7}

Why choose $B^0/B_s \to \pi^o\pi^o$?

- Clear dependence on detector and reconstruction performance
  - $\pi^o \to \gamma\gamma$, EM object, ECAL performance
  - Bs, b-tagging, background rejection

- CEPC can achieve Tera-Z (~10^{10} Bs) >> LEP
  - promising to observe this rare decay

ELSEVIER

16 November 1995

PHYSICS LETTERS B

Physics Letters B 363 (1995) 127–136

Search for neutral charmless B decays at LEP

L3 Collaboration

Since no candidate event has been found in data for any of the eight final configurations, upper limits at 90% confidence level have been set using the following numerical values: $N_{had} = 3\,088\,053$ as the number of Z bosons decaying to hadrons, $\Gamma_{\bar{b}}/\Gamma_{had} = 0.222 \pm 0.003(\text{stat.}) \pm 0.007(\text{syst.})$ as the partial width of Z decays into b quark with respect to the hadronic decays [20], $f(b \to B^0_d) = 39.5 \pm 4.0\%$ and $f(b \to B^0_s) = 12.0 \pm 3.0\%$ as the fractions of $B^0_{d(s)}$ produced in the fragmentation of b quarks at LEP, in agreement with the available measurements [21], $Br(\eta \to \gamma\gamma) = 38.8\%$ and $Br(\pi^0 \to \gamma\gamma) = 98.8\%$ [22]. The errors on

The following results are all based on fast simulation…

Reconstruction of π⁰

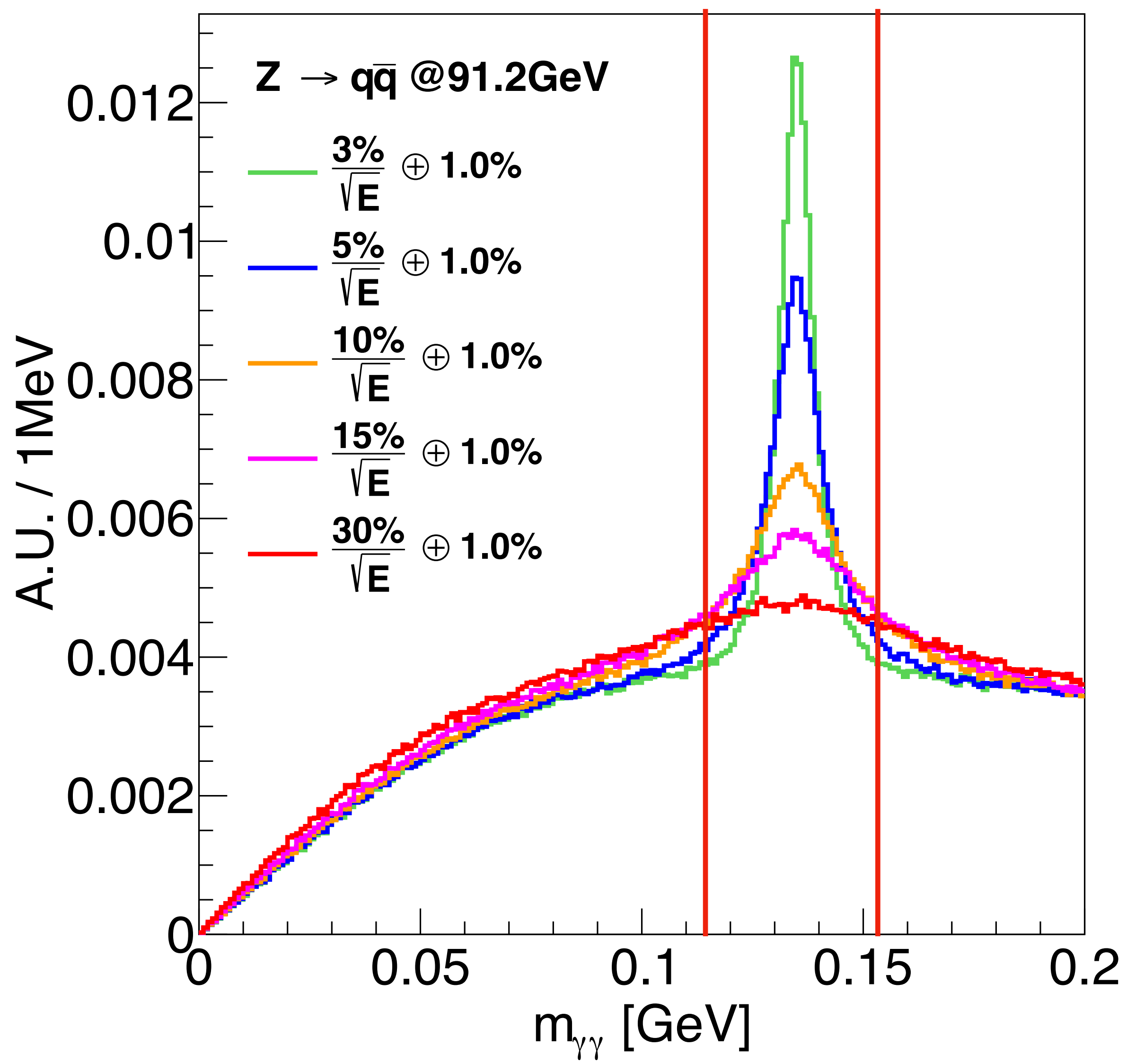
Decay channel: $\pi^0 \rightarrow \gamma\gamma$

Pair up photons and select π^0 candidates according to the invariant mass

Optimize the mass window to get maximal efficiency × purity

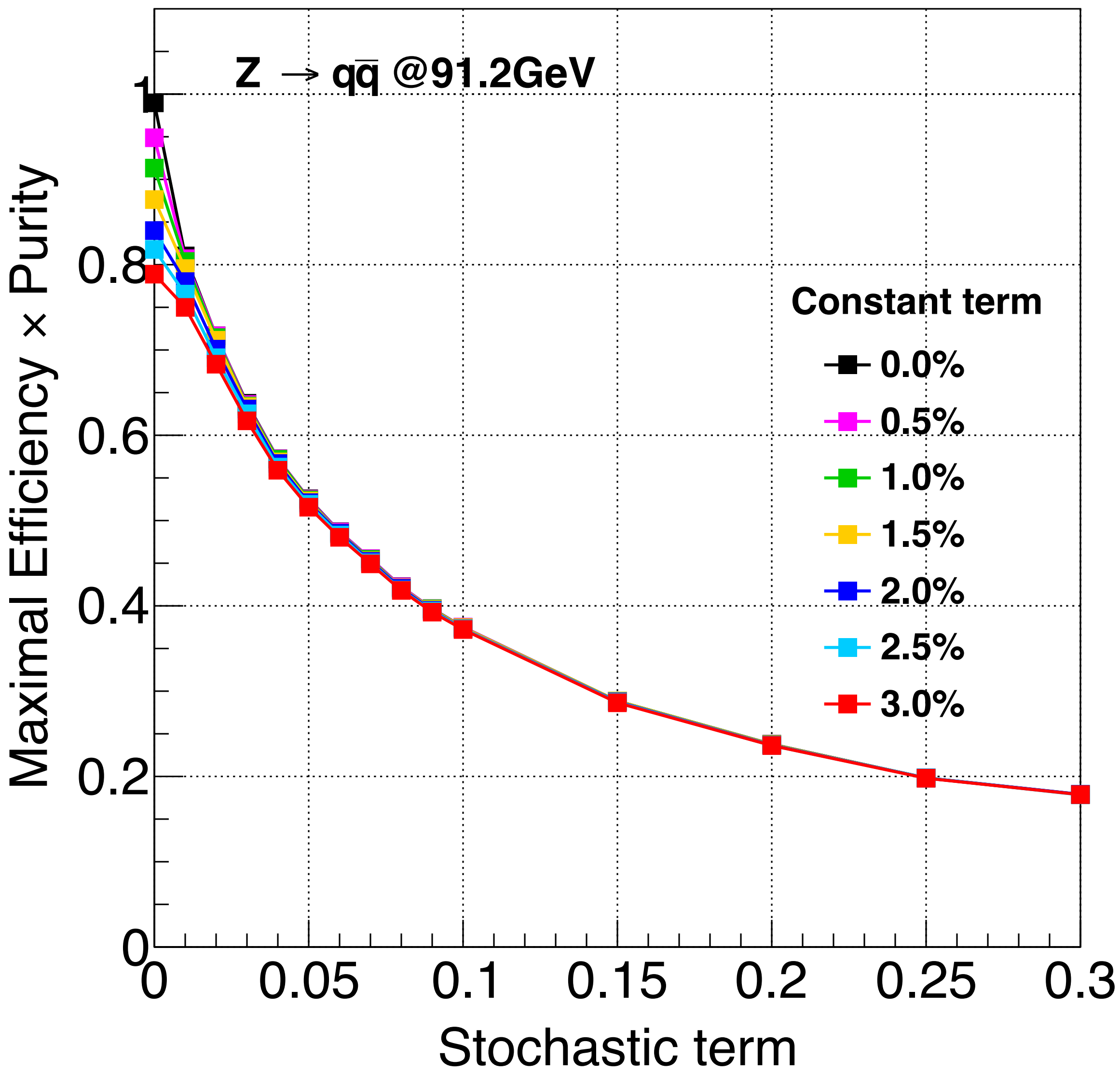
$$\epsilon = \frac{Number\ of\ selected\ \pi^0 s\ that\ are\ true\ \pi^0 s\ in\ Monte\ Carlo}{Number\ of\ all\ generated\ \pi^0 s}$$

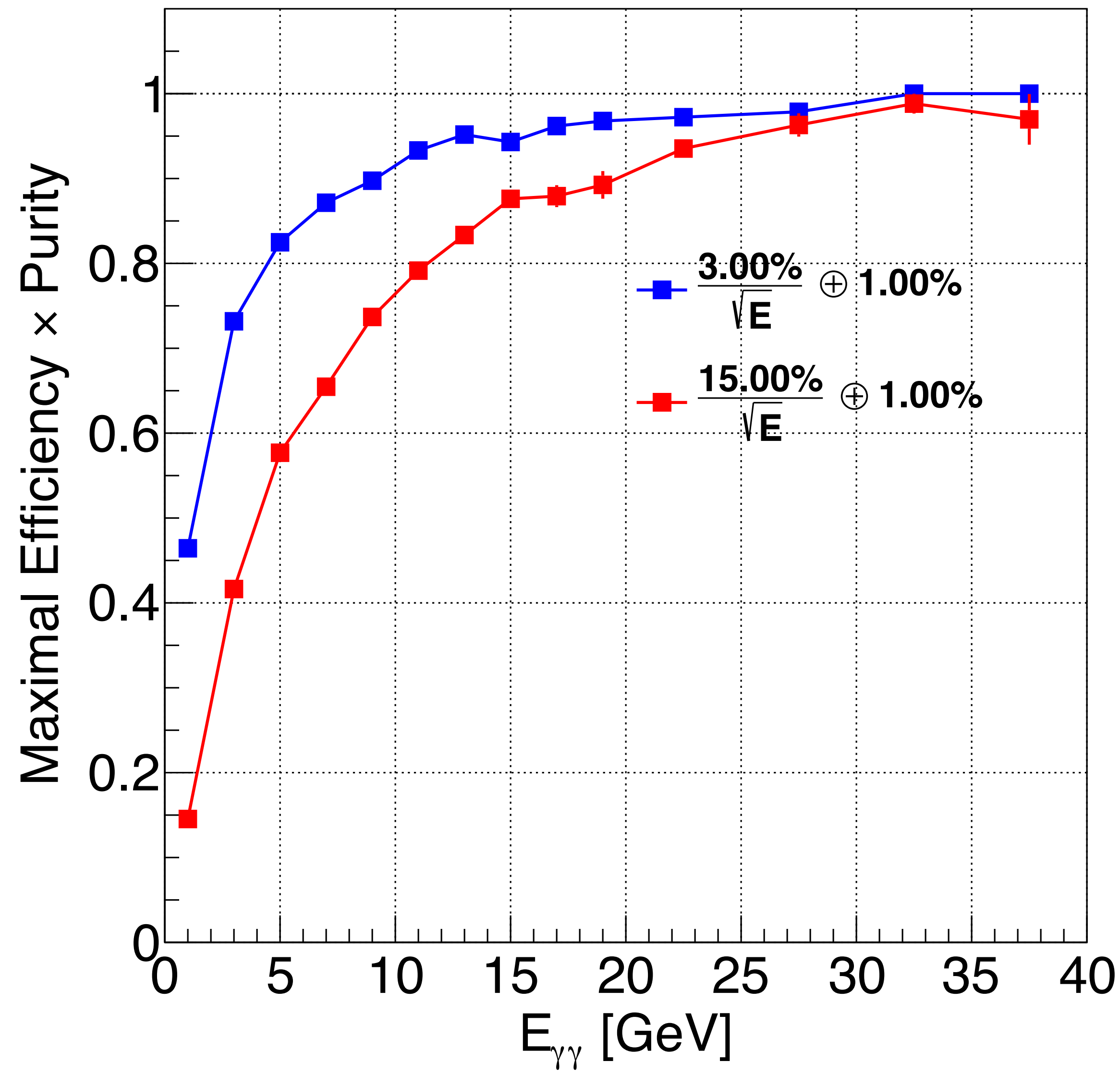
$$p = \frac{Number\ of\ selected\ \pi^0 s\ that\ are\ true\ \pi^0 s\ in\ Monte\ Carlo}{Number\ of\ all\ selected\ \pi^0 s}$$



Reconstruction of π°

Maximal efficiency × purity



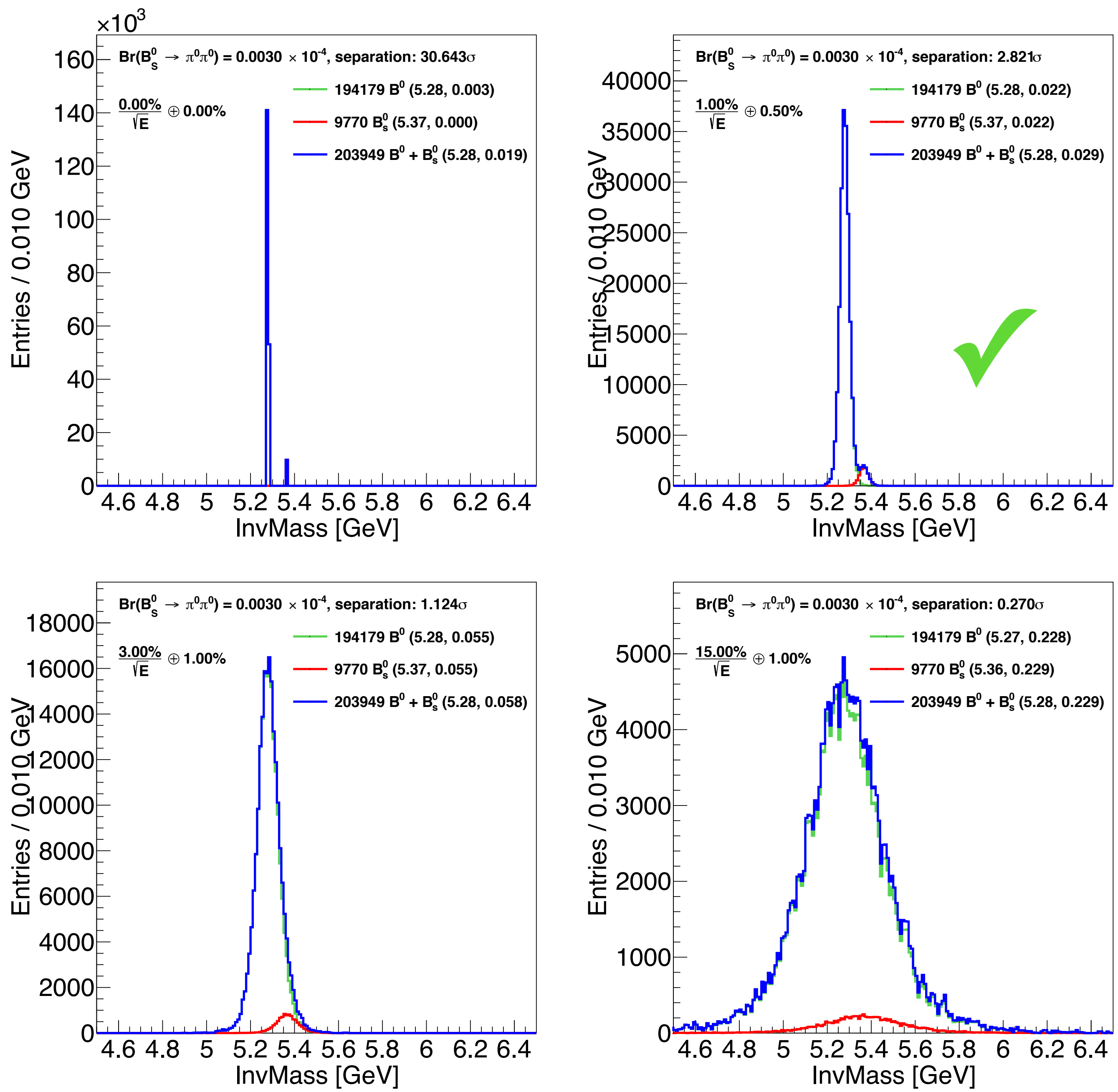


More details in CEPC Note: http://cepcdoc.ihep.ac.cn/DocDB/0002/000249/002/Pi0FastSimuReco.pdf

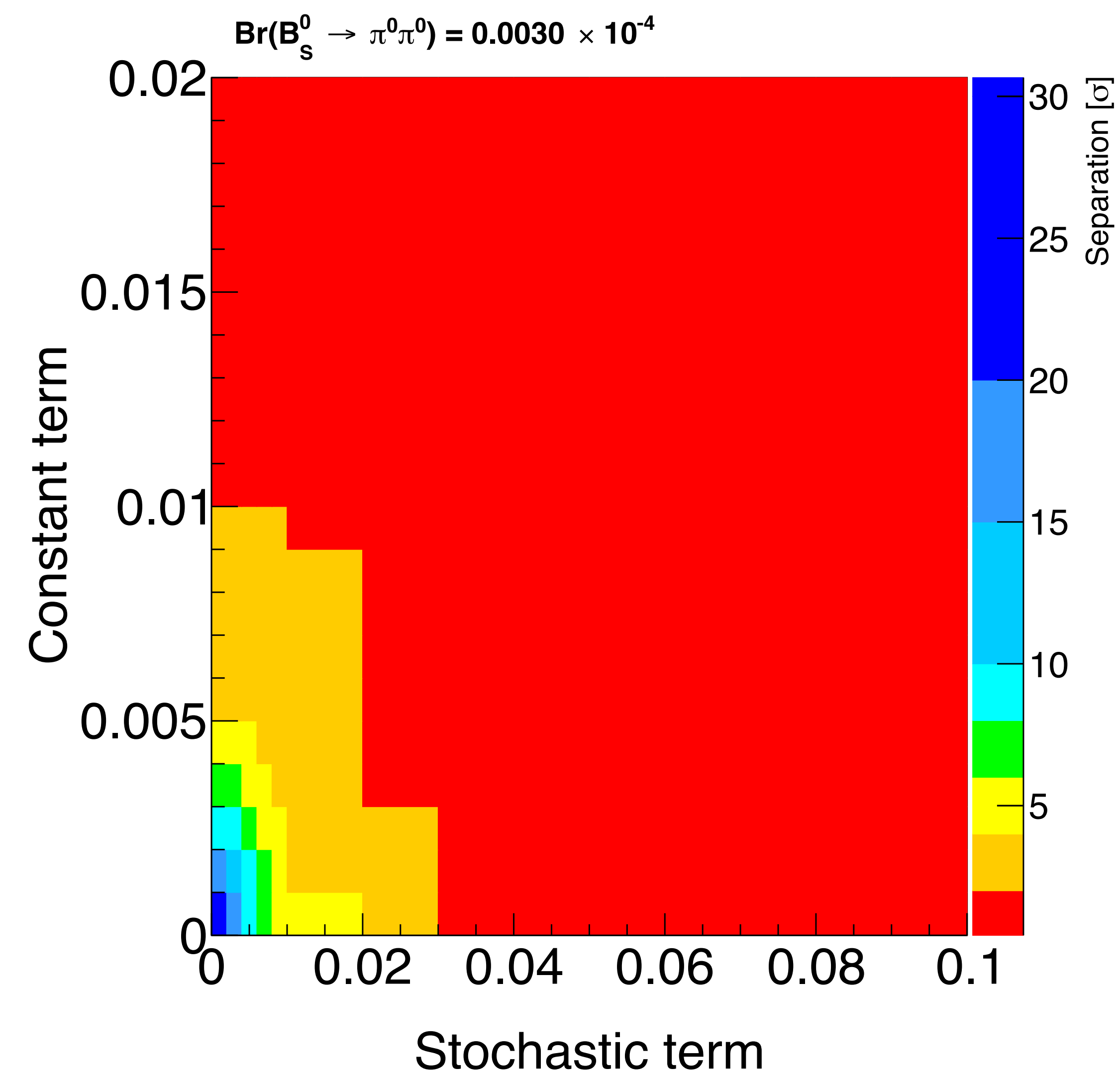
Separation of B⁰ and Bs

Mass $m_{B^0} = 5279.63 \pm 0.15$ MeV

Mass $m_{B_s^0} = 5366.89 \pm 0.19$ MeV

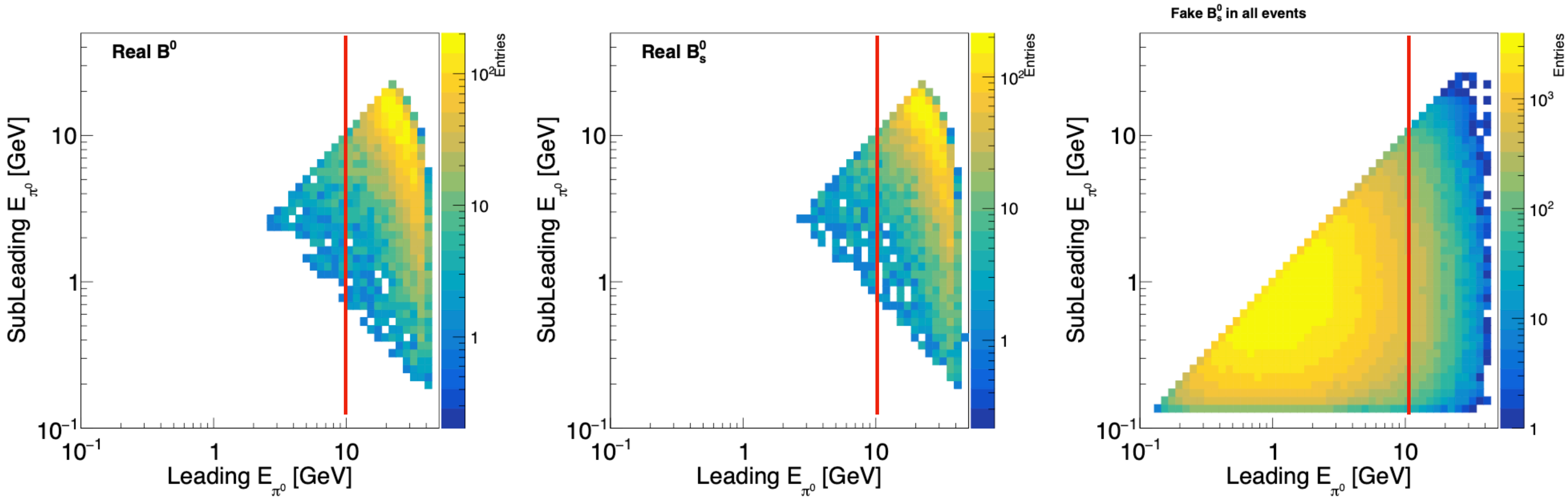


$$separation\ power = \frac{|\bar{m}_{B^0} - \bar{m}_{B_s^0}|}{\sqrt{\sigma^2_{m_{B^0}} + \sigma^2_{m_{B_s^0}}}}$$

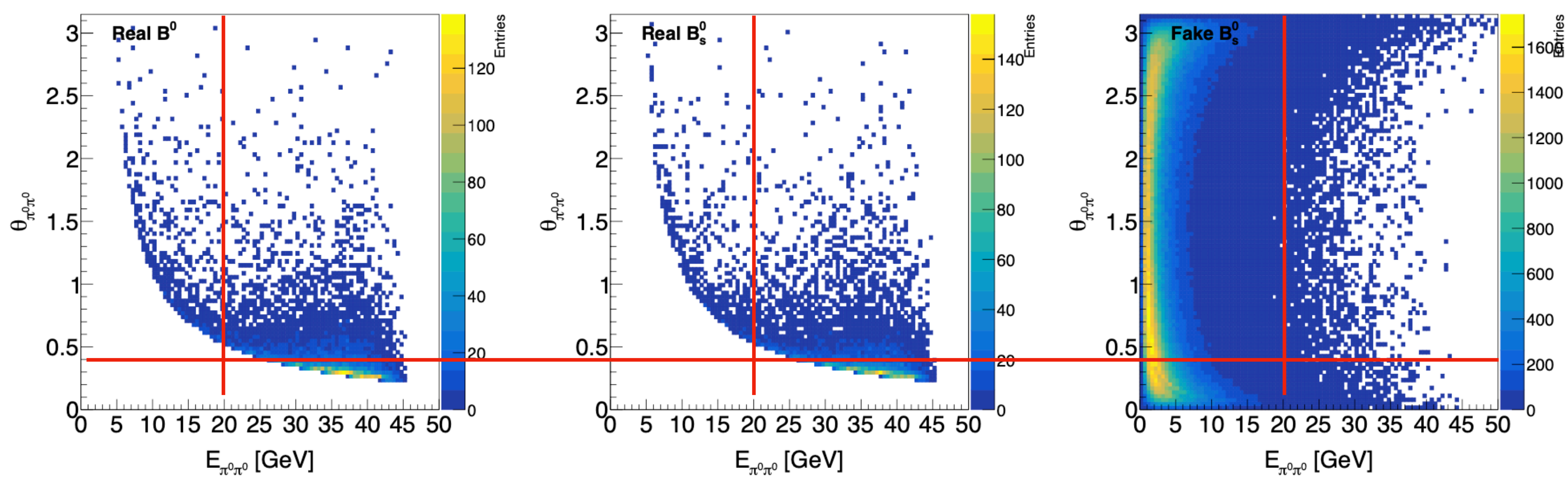


ECAL energy resolution better than 1%/√E⊕0.5% is required.

MCTruth Distribution of B⁰/Bs → π°π°



(a) Energy spectrum of π^0 pairs in $B^0 \to \pi^0\pi^0$ (left), $B_s^0 \to \pi^0\pi^0$ (middle), and $Z \to q\bar{q}$ (right) events.



(b) $\theta_{\pi^0\pi^0}$ vs $E_{\pi^0\pi^0}$ in $B^0 \to \pi^0\pi^0$ (left), $B_s^0 \to \pi^0\pi^0$ (middle), and $Z \to q\bar{q}$ (right) events.

Cut chain

134 *L3 Collaboration / Physics Letters B 363 (1995) 127–136*

Table 1
Final cuts for all the B^0_d and B^0_s decay modes. The (I) and (II) modes refer to the search for a four photon final state, or one with a photon pair for one η and a single cluster for the other one, respectively. "Kinematics" refers to global kinematic variables of the $B^0_{d(s)}$ candidate, "Photons", "Cluster" and "2nd cluster" to the cuts on purity of photons, single cluster or most energetic π^0 single cluster, if any.

	Cut	$B^0_{d(s)} \to \eta\eta$ (I)	$B^0_{d(s)} \to \eta\eta$ (II)	$B^0_{d(s)} \to \eta\pi^0$	$B^0_{d(s)} \to \pi^0\pi^0$
Kinematics	$M_{\gamma\gamma}$ (GeV)	0.51–0.58	0.530–0.564	0.530–0.564	–
	$\cos\theta^*$	0.7	0.775	0.75	0.6
	θ_{mesons}	28°	25°	26°	23°
	Total energy	17.0	27.5	25.0	22.0
Photons	Energy (GeV)	0.3	0.5	1.0	–
	χ^2_{em}	10.0	8.0	8.0	–
	θ_{3D} (mrad)	30.0	50.0	50.0	–
Cluster	Energy (GeV)	–	10.0	13.0	6.0
	χ^2_{em}	–	–	8.0	30.0
	θ_{3D} (mrad)	–	50.0	50.0	40.0
2nd cluster	Energy (GeV)	–	–	–	14.0
	χ^2_{em}	–	–	–	5.0
	θ_{3D} (mrad)	–	–	–	40.0

As a starting point, just use the values in L3 paper:

Pi0 Emin > 6GeV & Emax > 14GeV & Total E > 22GeV & angle < 23º

Measure $B^0/B_s \to \pi^o\pi^o$ individually

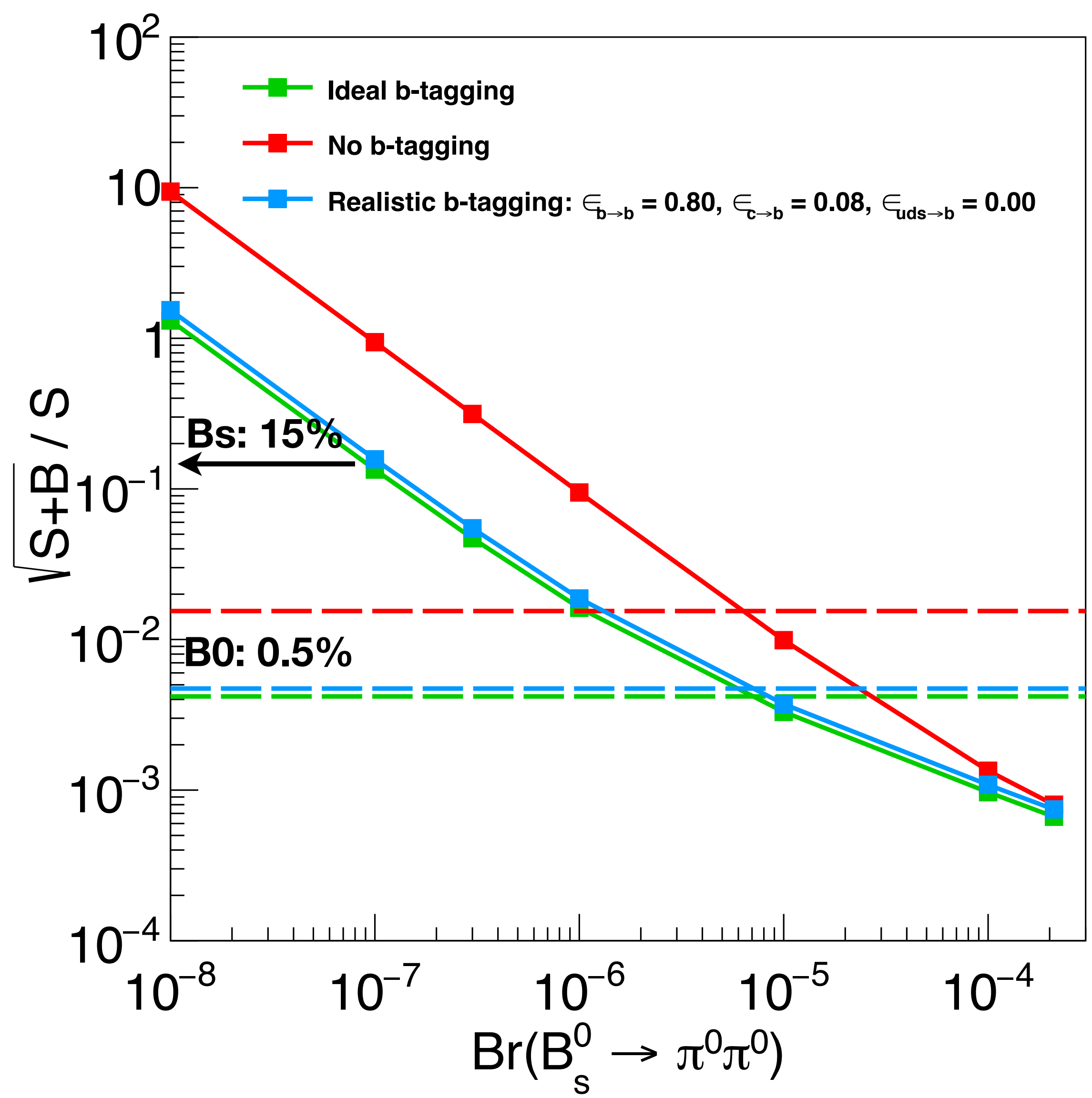
at $1\%/\sqrt{E} \oplus 0.5\%$ ECAL resolution

An artificial sample contains 1e4 $B0/Bs \to \pi^o\pi^o$ signal and 2.4e8 $Z \to qq$ background

Cut chain

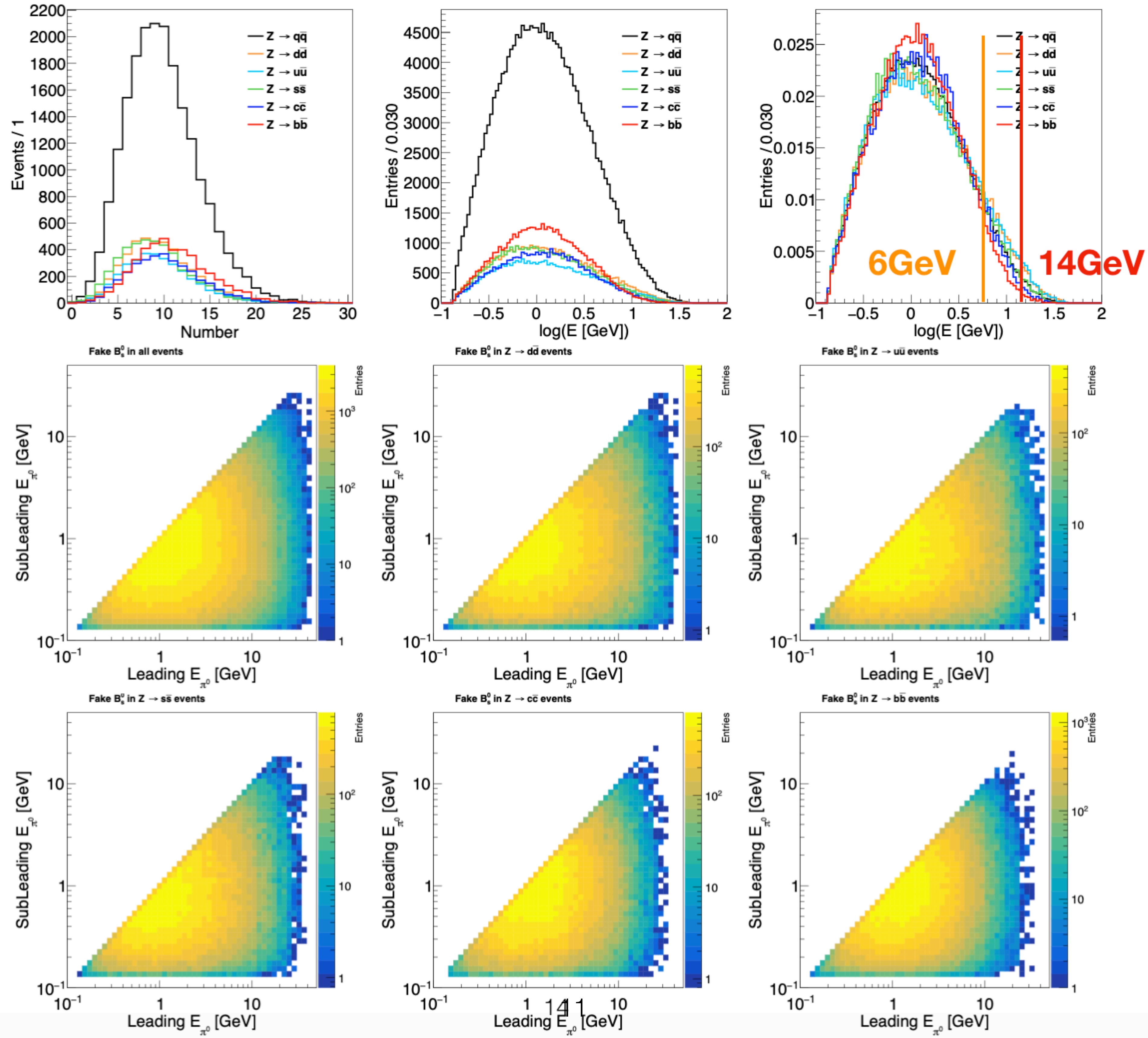
	B0 mass window (5.20, 5.36) GeV				
	Sig	Bkg_All	Bkg_uds	Bkg_c	Bkg_b
No cut	9551	46145880	25644234	8524421	11977225
Emin > 6GeV	5917	15633	12608	1765	1260
Emax > 14GeV	5590	1744	1584	104	56
ESum > 22GeV	5574	1424	1308	70	46
Angle < 23º	4987	274	266	4	4
	Bs mass window (5.29, 5.45) GeV				
	Sig	Bkg_All	Bkg_uds	Bkg_c	Bkg_b
No cut	9549	44494734	24781183	8215742	11497809
Emin > 6GeV	6005	15254	12195	1775	1284
Emax > 14GeV	5666	1787	1625	101	61
ESum > 22GeV	5645	1457	1329	78	50
Angle < 23º	4975	259	249	5	5

Just raw data, need to be scaled to Tera-Z



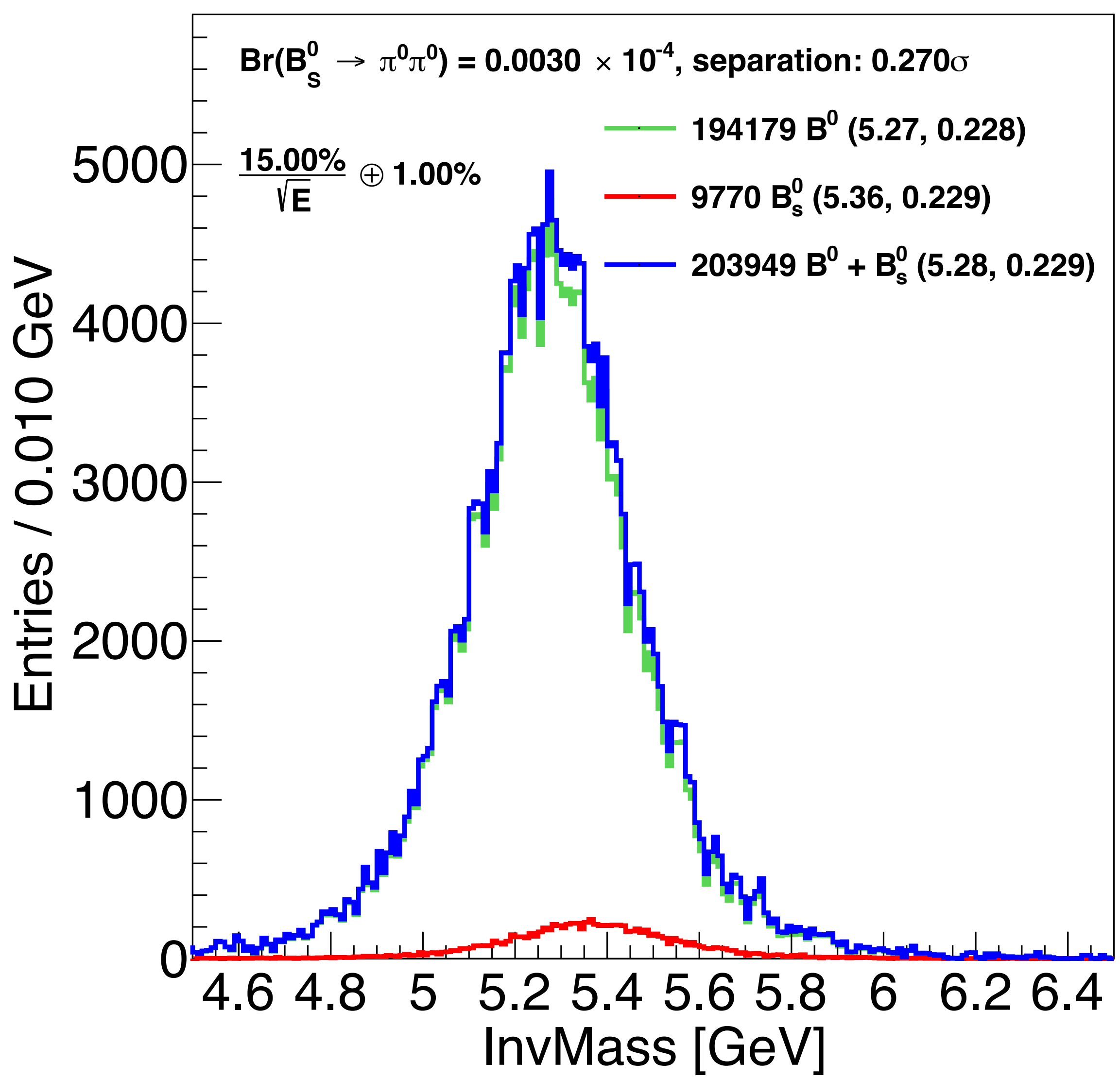
Further understanding on the effect of b-tagging

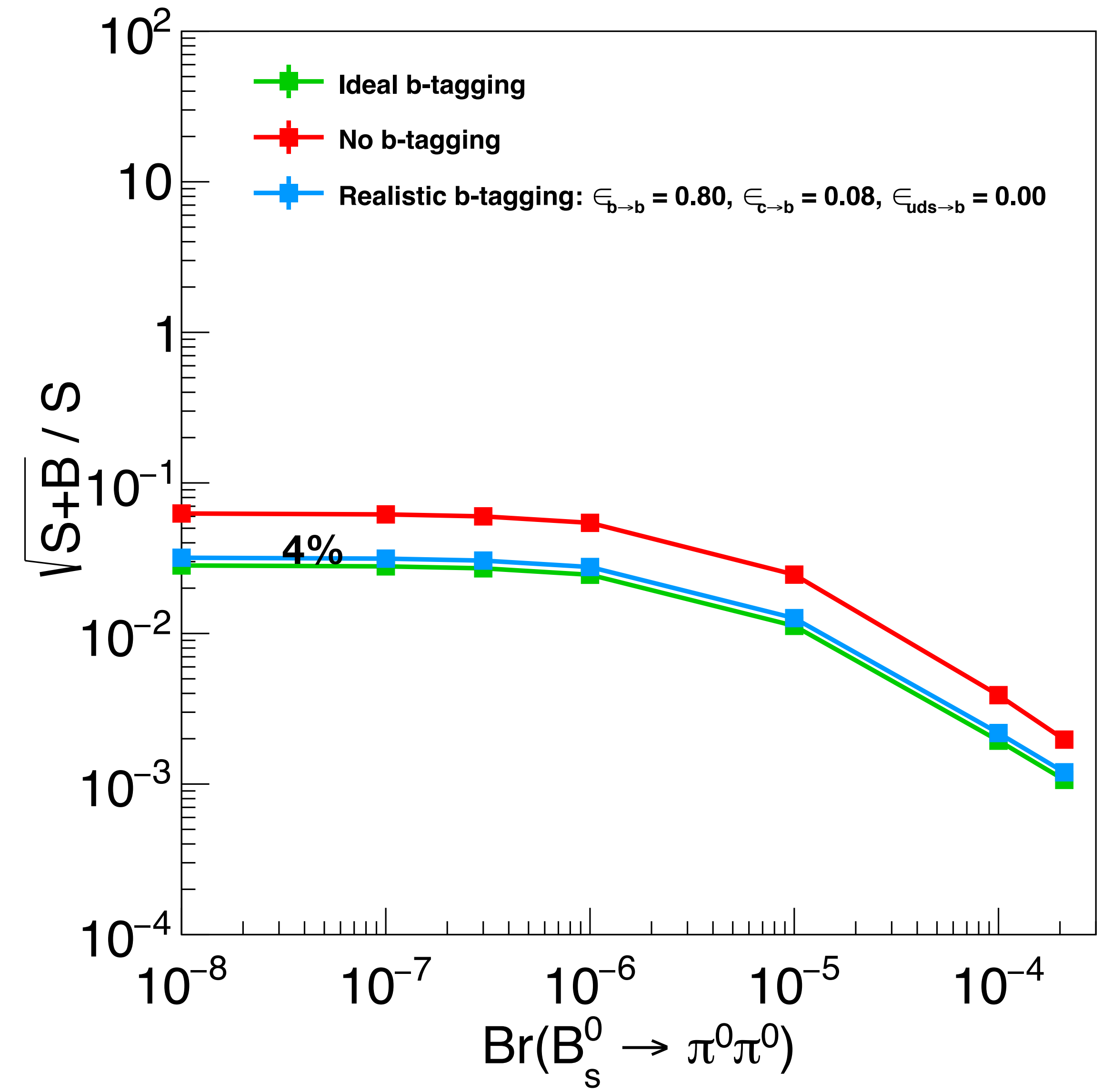
π° energy spectrum differs in different quark flavor events



Mixed measurement of $B^0/B_s \rightarrow \pi^o\pi^o$

at $15\%/\sqrt{E} \oplus 1\%$ ECAL resolution





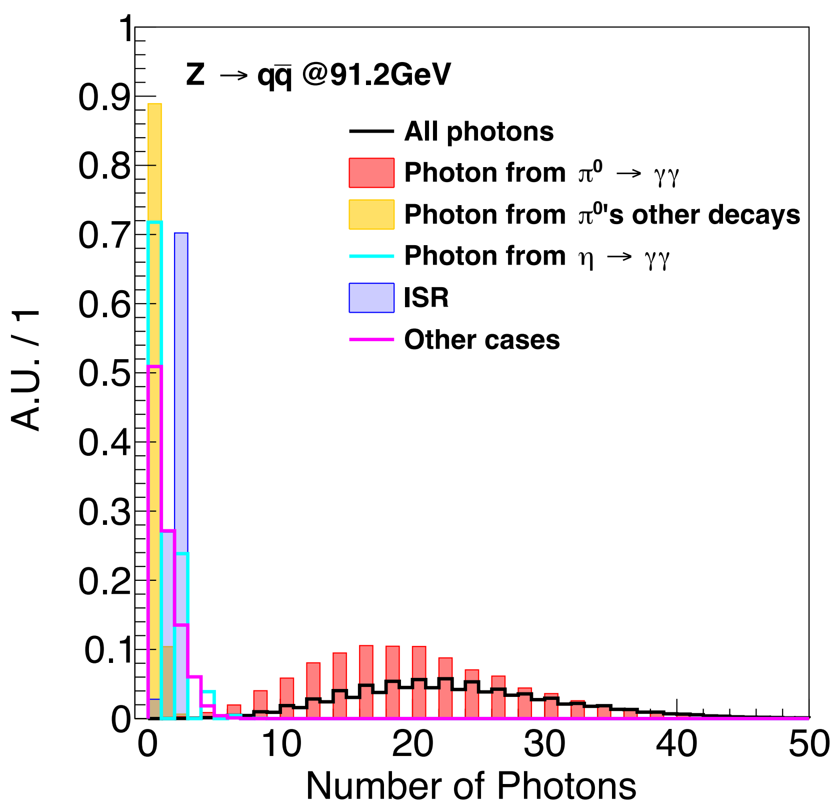
$BR(B_s \rightarrow \pi^o\pi^o)$ can also be estimated by using the $BR(B^0 \rightarrow \pi^o\pi^o)$ measured in other experiments…

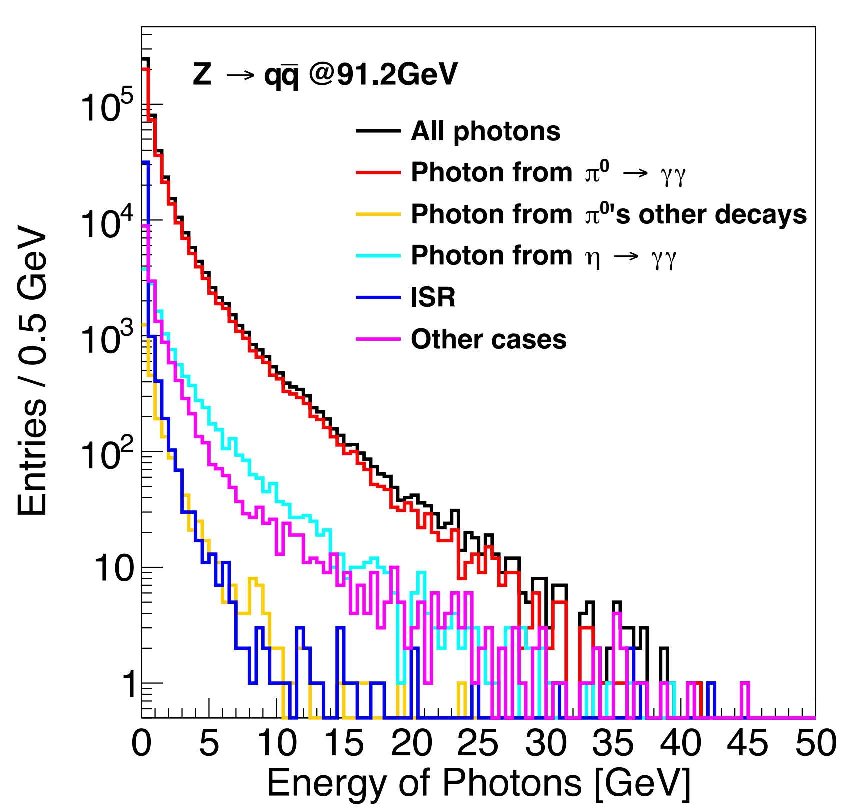
Next step…

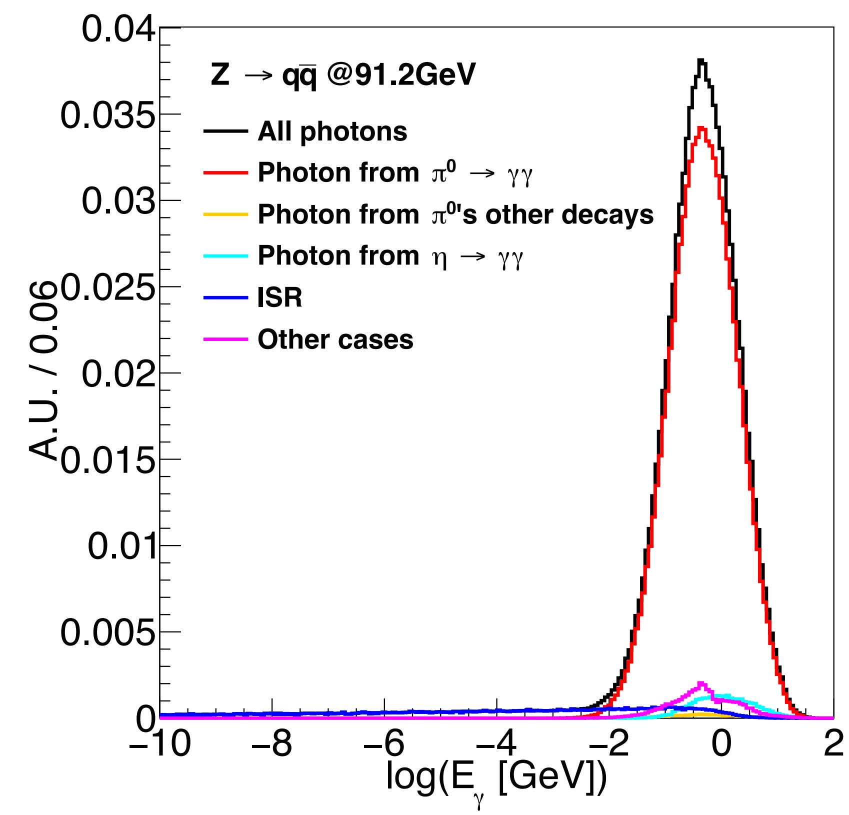
Further evaluation of the impact of some realistic physics effects:

- **Energy threshold**
- **Acceptance**
- **Separation of nearby photons**
- **Fake photons**
- **…**

Reconstruction of η → γγ







Summary

Fast simulation study

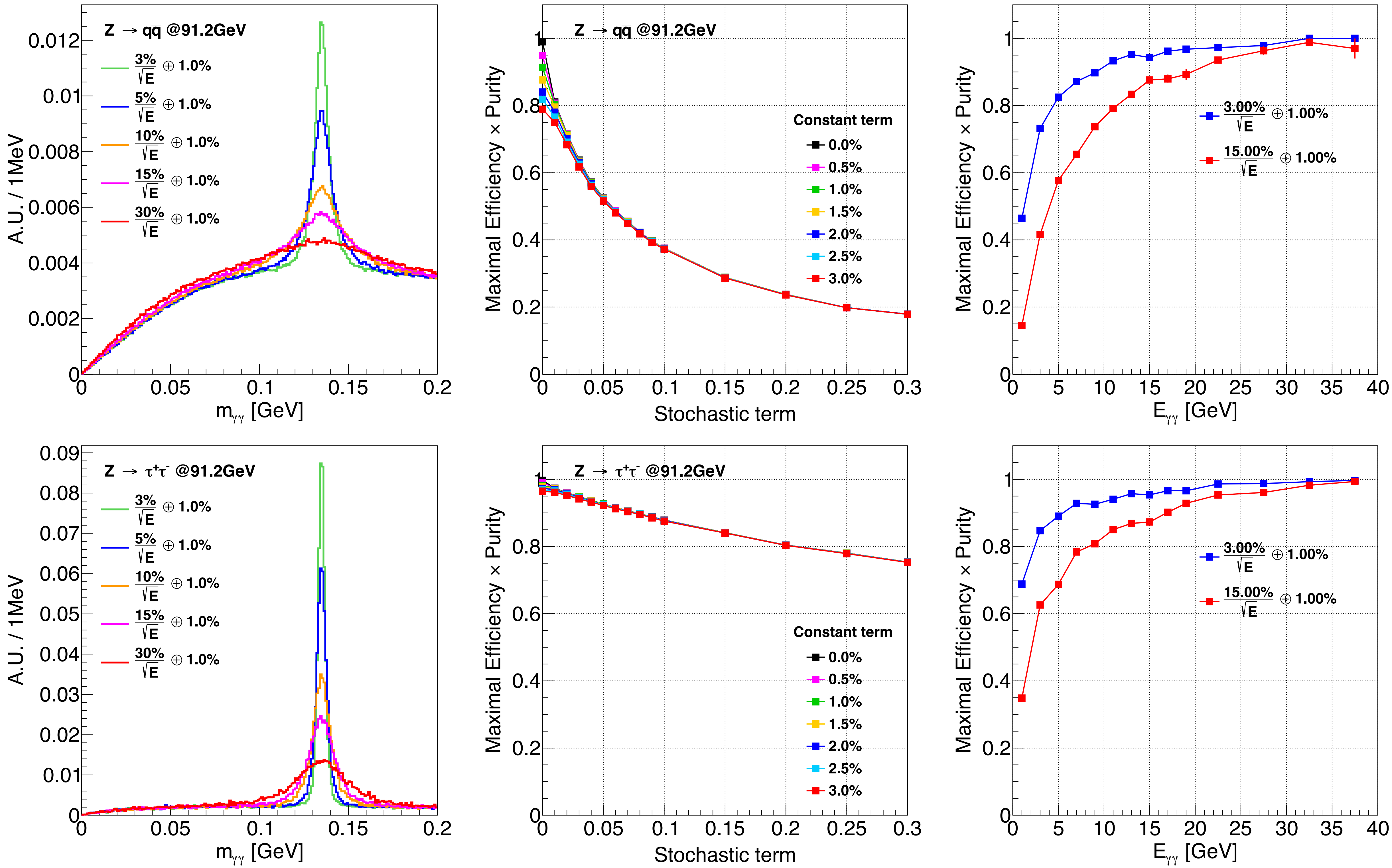
- Reconstruction of π^0
  - dependence on ECAL resolution and π^0 energy (sample dependent)
- Separation of B^0 & Bs
  - strong limitation on ECAL resolution
    - stochastic term better than 1%
    - constant term better than 0.5%
- Individual measurement of B^0 & Bs $\to \pi^0\pi^0$
- Mixed measurement of B^0 & Bs $\to \pi^0\pi^0$
- B-tagging is necessary
- Future works
  - Further evaluate the impact of some realistic physics effects
  - Reconstruction of $\eta \to \gamma\gamma$

Thanks!

Backup

π^0 reconstruction performance

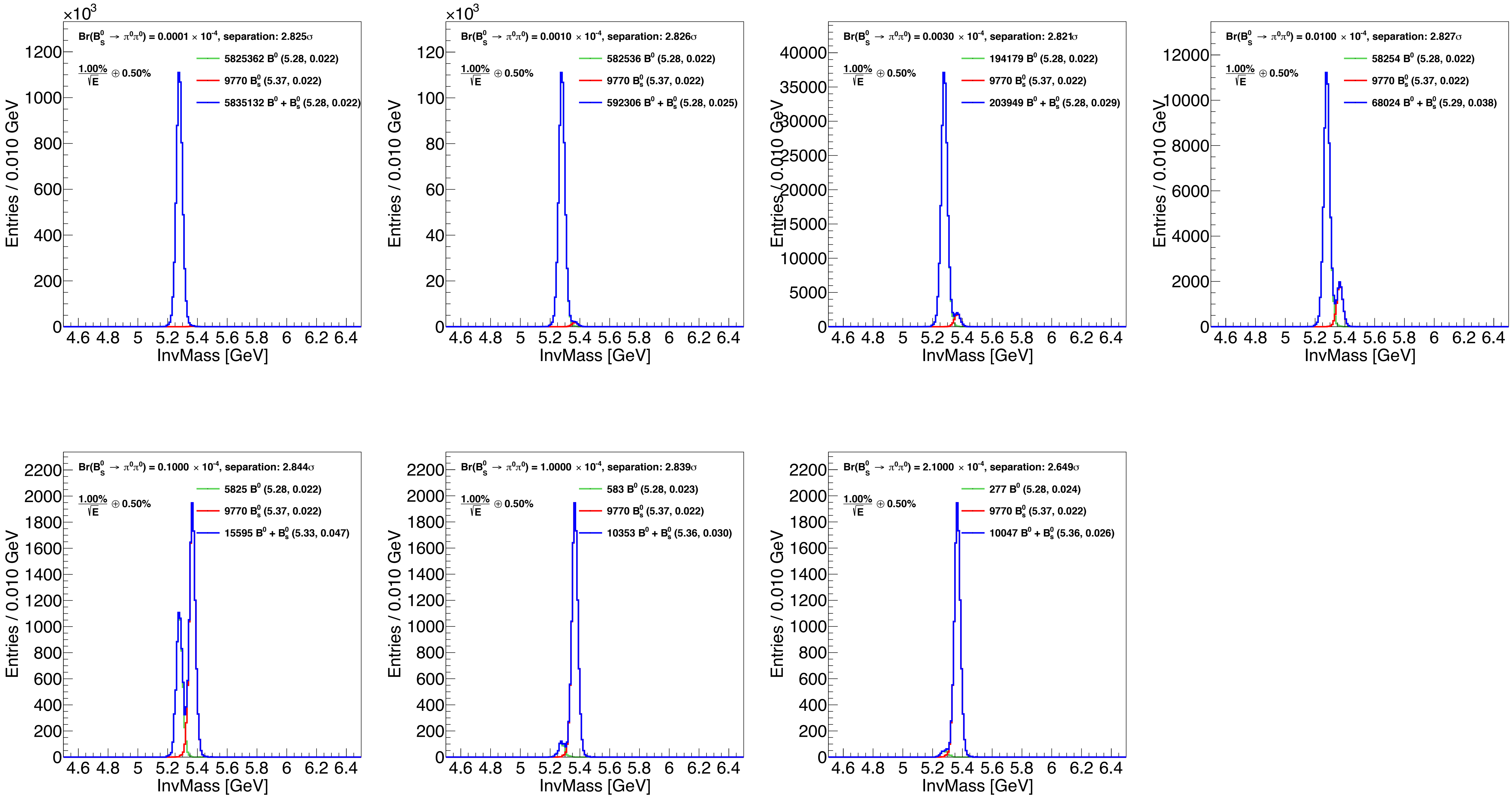
Fast simulation analysis



✔ The first draft of CEPC Note has finished.

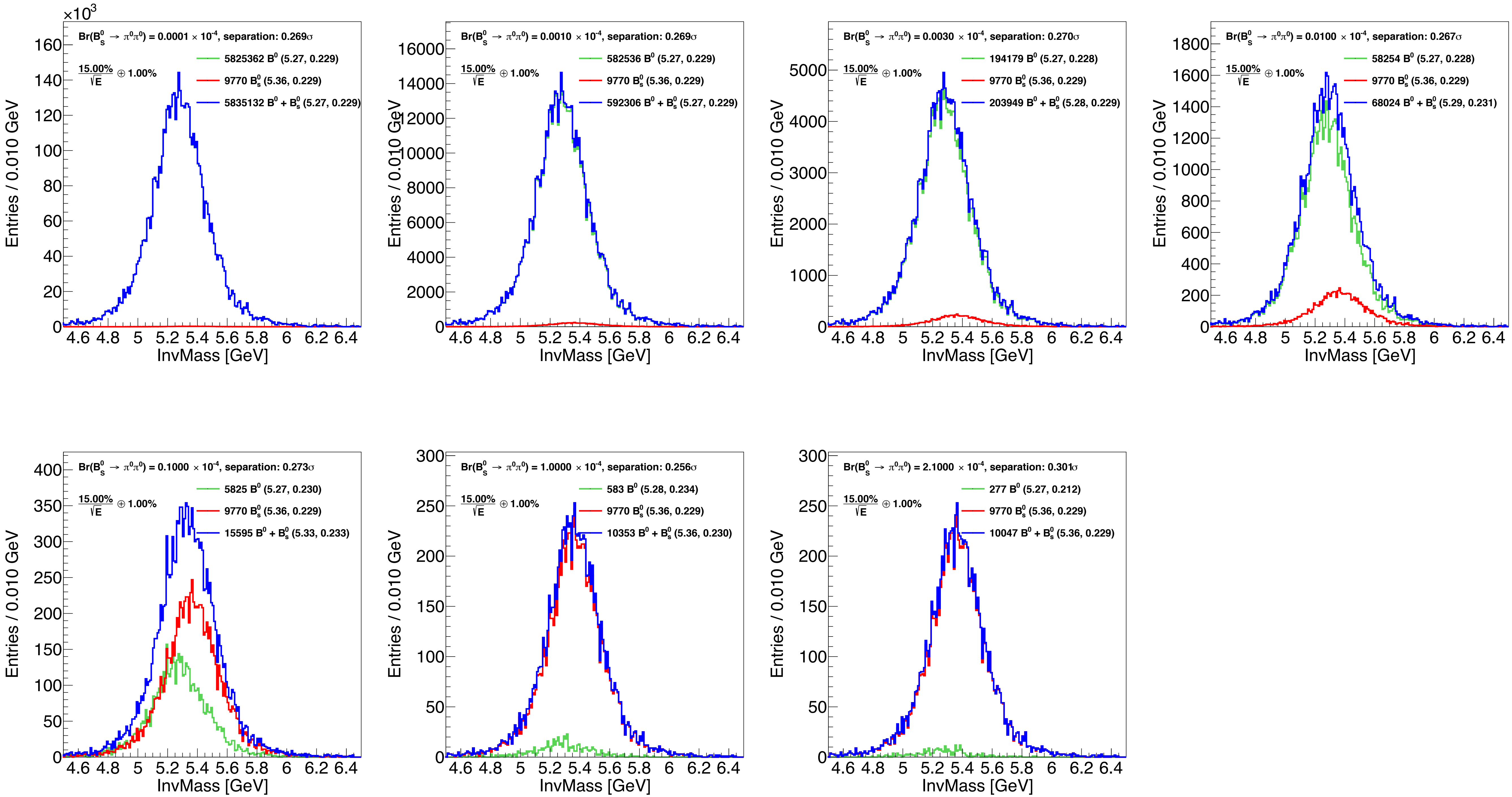
Separation of B^0 and Bs

at 1%/√E⊕0.5% ECAL resolution
varying BR(Bs → π°π°) from 10^{-8} to 2.1×10^{-4}

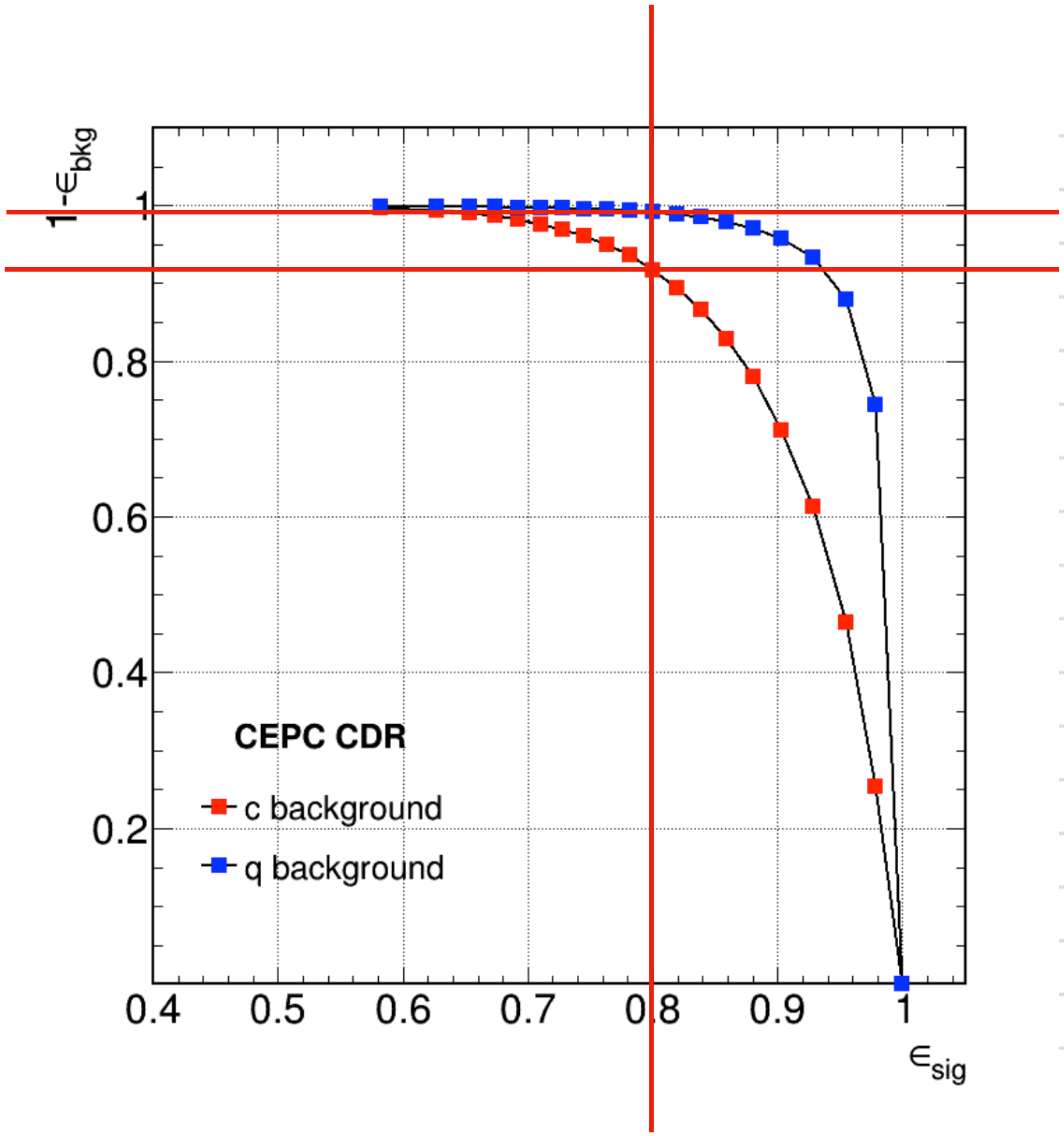


Separation of B⁰ and Bs

at 15%/√E⊕1% ECAL resolution
varying BR(Bs → $\pi^0\pi^0$) from 10^{-8} to 2.1×10^{-4}



b-tagging efficiency



eff_bb	eff_cb	eff_qb	Purity	eff*pur
1	1	1	0.216	0.216
0.98	0.75	0.25	0.4287798	0.4202042
0.96	0.54	0.13	0.5459716	0.5241327
0.93	0.39	0.06	0.6593147	0.6131627
0.9	0.3	0.05	0.70282	0.632538
0.88	0.22	0.03	0.7718045	0.6791879
0.86	0.17	0.02	0.8174617	0.7030171
0.84	0.14	0.01	0.8573049	0.7201361
0.82	0.1	0.005	0.8973554	0.7358314
0.8	0.08	0	0.9262436	0.7409949
0.78	0.06	0	0.9422819	0.7349799
0.76	0.05	0	0.95022	0.7221672
0.74	0.04	0	0.9587332	0.7094626
0.72	0.03	0	0.9678865	0.6968783
0.69	0.01	0	0.9885911	0.6821279
0.58	0	0	1	0.58

Introduction of $B^0 \to \pi^o\pi^o$

$\Gamma(\pi^0\pi^0)/\Gamma_{total}$ **in PDG 2018** Γ_{388}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
1.59±0.26 OUR AVERAGE		Error includes scale factor of 1.4.			
1.31±0.19±0.19		[1] JULIUS	17	BELL	$e^+e^- \to \Upsilon(4S)$
1.83±0.21±0.13		[1] LEES	13D	BABR	$e^+e^- \to \Upsilon(4S)$

PHYSICAL REVIEW D **96,** 032007 (2017)

Measurement of the branching fraction and *CP* asymmetry in $B^0 \to \pi^0\pi^0$ decays, and an improved constraint on ϕ_2

T. Julius,[43] M. E. Sevior,[43] G. B. Mohanty,[66] I. Adachi,[14,11] H. Aihara,[70] S. Al Said,[65,32] D. M. Asner,[58] V. Aulchenko,[3,56] T. Aushev,[46] R. Ayad,[65] V. Babu,[66] I. Badhrees,[65,31] A. M. Bakich,[64] V. Bansal,[58] E. Barberio,[43] M. Barrett,[13] M. Berger,[62] V. Bhardwaj,[16] B. Bhuyan,[18] J. Biswal,[27] T. Bloomfield,[43] A. Bobrov,[3,56] A. Bondar,[3,56] G. Bonvicini,[75] A. Bozek,[53] M. Bračko,[41,27] T. E. Browder,[13] D. Červenkov,[4] M.-C. Chang,[9] Y. Chao,[52] V. Chekelian,[42] A. Chen,[50] B. G. Cheon,[12] K. Chilikin,[37,45] K. Cho,[33] Y. Choi,[63] D. Cinabro,[75] N. Dash,[17] S. Di Carlo,[75] Z. Doležal,[4] D. Dossett,[43] Z. Drásal,[4] D. Dutta,[66] S. Eidelman,[3,56] H. Farhat,[75] J. E. Fast,[58] T. Ferber,[7] B. G. Fulsom,[58] V. Gaur,[74] N. Gabyshev,[3,56] A. Garmash,[3,56] R. Gillard,[75] P. Goldenzweig,[29] J. Haba,[14,11] T. Hara,[14,11] K. Hayasaka,[55] H. Hayashii,[49] W.-S. Hou,[52] C.-L. Hsu,[43] T. Iijima,[48,47] K. Inami,[47] A. Ishikawa,[68] R. Itoh,[14,11] Y. Iwasaki,[14] W. W. Jacobs,[20] I. Jaegle,[8] Y. Jin,[70] D. Joffe,[30] K. K. Joo,[5] J. Kahn,[39] G. Karyan,[7] P. Katrenko,[46,37] T. Kawasaki,[55] C. Kiesling,[42] D. Y. Kim,[61] H. J. Kim,[35] J. B. Kim,[34] K. T. Kim,[34]

We measure the branching fraction and *CP* violation asymmetry in the decay $B^0 \to \pi^0\pi^0$, using a data sample of 752×10^6 $B\bar{B}$ pairs collected at the $\Upsilon(4S)$ resonance with the Belle detector at the KEKB e^+e^- collider. The obtained branching fraction and direct *CP* asymmetry are $\mathcal{B}(B \to \pi^0\pi^0) = [1.31 \pm 0.19(\mathrm{stat}) \pm 0.19(\mathrm{syst})] \times 10^{-6}$ and $A_{CP} = +0.14 \pm 0.36(\mathrm{stat}) \pm 0.10(\mathrm{syst})$, respectively. The signal significance, including the systematic uncertainty, is 6.4 standard deviations. We combine these results with Belle's earlier measurements of $B^0 \to \pi^+\pi^-$ and $B^\pm \to \pi^\pm\pi^0$ to exclude the *CP*-violating parameter ϕ_2 from the range $15.5° < \phi_2 < 75.0°$ at 95% confidence level.

(Belle Collaboration)

https://journals.aps.org/prd/abstract/10.1103/PhysRevD.96.032007

Introduction of Bs → $\pi^o\pi^o$

Experimental upper limit

$\Gamma(\pi^0\pi^0)/\Gamma_{total}$ **in PDG 2018** Γ_{87}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
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[1] ACCIARRI 95H assumes $f_{B^0} = 39.5 \pm 4.0$ and $f_{B_s} = 12.0 \pm 3.0\%$.

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16 November 1995

PHYSICS LETTERS B

Physics Letters B 363 (1995) 127–136

Search for neutral charmless B decays at LEP

L3 Collaboration

https://www.sciencedirect.com/science/article/pii/037026939501042O

Table 2
Resolutions (σ of a Gaussian fit to the signal Monte Carlo invariant mass distribution), efficiencies and experimental limits for B^0_d and B^0_s branching ratios. The (I) and (II) modes refer respectively to the search for a four photon final state or one with a photon pair for one η and a single cluster for the other one. The first error on the efficiencies is statistical, the second systematic.

Process	Resolution (MeV)	Efficiency (%)	Upper limit 90% C.L.
$B^0_d \rightarrow \eta\eta$ (I)	107 ± 10	$2.5 \pm 0.2^{+0.2}_{-0.2}$	
$B^0_d \rightarrow \eta\eta$ (II)	146 ± 11	$4.6 \pm 0.3^{+0.02}_{-0.2}$	
$B^0_d \rightarrow \eta\eta$			$< 4.1 \times 10^{-4}$
$B^0_d \rightarrow \eta\pi^0$	79 ± 5	$4.5 \pm 0.3^{+0.05}_{-0.03}$	$< 2.5 \times 10^{-4}$
$B^0_d \rightarrow \pi^0\pi^0$	97 ± 4	$7.6 \pm 0.4^{+0.2}_{-0.5}$	$< 6.0 \times 10^{-5}$
$B^0_s \rightarrow \eta\eta$ (I)	101 ± 10	$2.4 \pm 0.2^{+0.2}_{-0.2}$	
$B^0_s \rightarrow \eta\eta$ (II)	129 ± 8	$4.8 \pm 0.3^{+0.2}_{-0.3}$	
$B^0_s \rightarrow \eta\eta$			$< 1.5 \times 10^{-3}$
$B^0_s \rightarrow \eta\pi^0$	81 ± 1	$4.3 \pm 0.3^{+0.02}_{-0.1}$	$< 1.0 \times 10^{-3}$
$B^0_s \rightarrow \pi^0\pi^0$	99 ± 4	$8.3 \pm 0.4^{+0.4}_{-0.7}$	$< 2.1 \times 10^{-4}$

Introduction of Bs → π°π°

Theoretical estimation

TABLE III. The *CP*-averaged branching ratios ($\times 10^{-6}$) of $B_s \to PP$ decays obtained in the pQCD approach (This work); the errors for these entries correspond to the uncertainties in the input hadronic quantities, from the scale dependence, and the CKM matrix elements, respectively. We have also listed the current experimental measurements and upper limits (90% C.L.) wherever available [13]. For comparison, we also cite the theoretical estimates of the branching ratios in the QCD factorization framework [16] and in SCET [20], quoting two estimates in the latter case for some decays.

Modes	Class	QCDF	SCET	This work	Experiment
$\bar{B}_s^0 \to K^+\pi^-$	T	$10.2^{+4.5+3.8+0.7+0.8}_{-3.9-3.2-1.2-0.7}$	$4.9 \pm 1.2 \pm 1.3 \pm 0.3$	$7.6^{+3.2+0.7+0.5}_{-2.3-0.7-0.5}$	$5.0 \pm 0.75 \pm 1.0$
$\bar{B}_s^0 \to K^0\pi^0$	C	$0.49^{+0.28+0.22+0.40+0.33}_{-0.24-0.14-0.14-0.17}$	$0.76 \pm 0.26 \pm 0.27 \pm 0.17$	$0.16^{+0.05+0.10+0.02}_{-0.04-0.05-0.01}$	
$\bar{B}_s^0 \to K^+K^-$	P	$22.7^{+3.5+12.7+2.0+24.1}_{-3.2-8.4-2.0-9.1}$	$18.2 \pm 6.7 \pm 1.1 \pm 0.5$	$13.6^{+4.2+7.5+0.7}_{-3.2-4.1-0.2}$	$24.4 \pm 1.4 \pm 4.6$
$\bar{B}_s^0 \to K^0\bar{K}^0$	P	$24.7^{+2.5+13.7+2.6+25.6}_{-2.4-9.2-2.9-9.8}$	$17.7 \pm 6.6 \pm 0.5 \pm 0.6$	$15.6^{+5.0+8.3+0.0}_{-3.8-4.7-0.0}$	
$\bar{B}_s^0 \to \pi^0\eta$	$P_{\rm EW}$	$0.075^{+0.013+0.030+0.008+0.010}_{-0.012-0.025-0.010-0.007}$	$0.014 \pm 0.004 \pm 0.005 \pm 0.004$	$0.05^{+0.02+0.01+0.00}_{-0.02-0.01-0.00}$	<1000
			$0.016 \pm 0.0007 \pm 0.005 \pm 0.006$		
$\bar{B}_s^0 \to \pi^0\eta'$	$P_{\rm EW}$	$0.11^{+0.02+0.04+0.01+0.01}_{-0.02-0.04-0.01-0.01}$	$0.006 \pm 0.003 \pm 0.002^{+0.064}_{-0.006}$	$0.11^{+0.05+0.02+0.00}_{-0.03-0.01-0.00}$	
			$0.038 \pm 0.013 \pm 0.016^{+0.260}_{-0.036}$		
$\bar{B}_s^0 \to K^0\eta$	C	$0.34^{+0.19+0.64+0.21+0.16}_{-0.16-0.27-0.07-0.08}$	$0.80 \pm 0.48 \pm 0.29 \pm 0.18$	$0.11^{+0.05+0.06+0.01}_{-0.03-0.03-0.01}$	
			$0.59 \pm 0.34 \pm 0.24 \pm 0.15$		
$\bar{B}_s^0 \to K^0\eta'$	C	$2.0^{+0.3+1.5+0.6+1.5}_{-0.3-1.1-0.3-0.6}$	$4.5 \pm 1.5 \pm 0.4 \pm 0.5$	$0.72^{+0.20+0.28+0.11}_{-0.16-0.17-0.05}$	
			$3.9 \pm 1.3 \pm 0.5 \pm 0.4$		
$\bar{B}_s^0 \to \eta\eta$	P	$15.6^{+1.6+9.9+2.2+13.5}_{-1.5-6.8-2.5-5.5}$	$7.1 \pm 6.4 \pm 0.2 \pm 0.8$	$8.0^{+2.6+4.7+0.0}_{-1.9-2.5-0.0}$	<1500
			$6.4 \pm 6.3 \pm 0.1 \pm 0.7$		
$\bar{B}_s^0 \to \eta\eta'$	P	$54.0^{+5.5+32.4+8.3+40.5}_{-5.2-22.4-6.4-16.7}$	$24.0 \pm 13.6 \pm 1.4 \pm 2.7$	$21.0^{+6.0+10.0+0.0}_{-4.6-5.6-0.0}$	
			$23.8 \pm 13.2 \pm 1.6 \pm 2.9$		
$\bar{B}_s^0 \to \eta'\eta'$	P	$41.7^{+4.2+26.3+15.2+36.6}_{-4.0-17.2-8.5-15.4}$	$44.3 \pm 19.7 \pm 2.3 \pm 17.1$	$14.0^{+3.2+6.2+0.0}_{-2.7-3.9-0.0}$	
			$49.4 \pm 20.6 \pm 8.4 \pm 16.2$		
$\bar{B}_s^0 \to \pi^+\pi^-$	ann	$0.024^{+0.003+0.025+0.000+0.163}_{-0.003-0.012-0.000-0.021}$	...	$0.57^{+0.16+0.09+0.01}_{-0.13-0.10-0.00}$	<1.36
$\bar{B}_s^0 \to \pi^0\pi^0$	ann	$0.012^{+0.001+0.013+0.000+0.082}_{-0.001-0.006-0.000-0.011}$	...	$0.28^{+0.08+0.04+0.01}_{-0.07-0.05-0.00}$	<210

~ 3×10^{-7}

https://journals.aps.org/prd/abstract/10.1103/PhysRevD.76.074018

Unique Opportunities at Z pole

Giga-Z, Tera-Z and 10×Tera-Z: a phase of future linear/circular lepton colliders. [Fujii et al.(2019), Dong et al.(2018), Abada et al.(2019)]

Z factories are also $b(c/\tau)$ factories:

Channel	Belle II	LHCb	Giga-Z	Tera-Z	10×Tera-Z
B^0, $\bar{B}^0$	5.3×10^{10}	$\sim 6 \times 10^{13}$	1.2×10^{8}	1.2×10^{11}	1.2×10^{12}
$B^\pm$	5.6×10^{10}	$\sim 6 \times 10^{13}$	1.2×10^{8}	1.2×10^{11}	1.2×10^{12}
B_s, $\bar{B}_s$	5.7×10^{8}	$\sim 2 \times 10^{13}$	3.2×10^{7}	3.2×10^{10}	3.2×10^{11}
$B_c^\pm$	-	$\sim 4 \times 10^{11}$	2.2×10^{5}	2.2×10^{8}	2.2×10^{9}
Λ_b, $\bar{\Lambda}_b$	-	$\sim 2 \times 10^{13}$	1.0×10^{7}	1.0×10^{10}	1.0×10^{11}