Bhabha veto in hie/stt/tau

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From Koga-san

Trigger menu and rate in 2020c

Category	Trigger logic	rate (KHz)
CDC B physics	CDC three 2Dtrack, two 2Dtrack Δϕ>90deg	0.57
ECL B physics	ECL #cluster>3,	0.11,
	ECL Energy>1GeV	0.51
KLM τ/dark	KLM back to back, #CDC-KLM matching >0	0.45
CDC τ/dark	2D-short track ϕ>90deg two 2Dtrack Δϕ>30deg	0.34, 0.52
ECL τ/dark, bhabha	Several combinations of cluster and energy	2.03
Bhabha veto	ECL 3D Bhabha veto	0.50 (no prescale)
Others	Calibration etc.	0.41
Total L1		**3.5**

From Koga-san

L1 rate after Bhabha prescale in 2021 (e18r67)

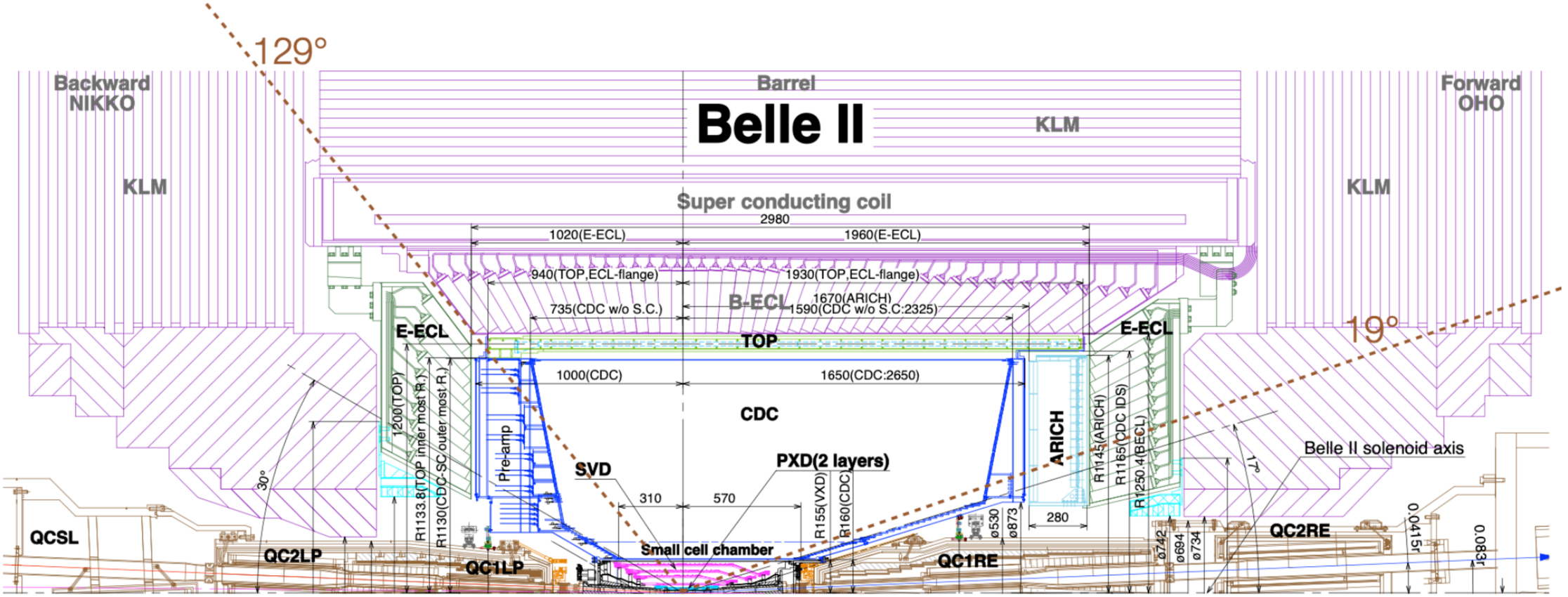
-L1 rate is ~2.5kHz @ L=1.5 × 10^34. Roughly consistent with expectation

		raw rate(KHz)	effect to L1(kHz)
CDC B physics	CDC three full track (ffy) two full track Δϕ>90deg (fyo)	0.13 0.19	**0.13** **0.11**
ECL B physics	ECL #cluster>3 (c4)	0.11	**0.05**
	ECL Energy>1GeV (hie)	0.56	**0.44 <- dominant**
KLM τ/dark	KLM back to back (mu_b2b, mu_eb2b, ,beklm,eklm2) #CDC/ECL-KLM matching (cdcklm1,seklm1,ieklm1,ecleklm1)	0.44 0.13	**0.40** **0.07**
CDC τ/dark	NN single track (stt) 2D-short track ϕ>90deg (yso,fioiecl1) two 2Dtrack Δϕ>30deg (fy30) Two inner tracks (ioiecl2)	0.44 0.19 0.22 0.17	**0.18 <- 2nd dominant** **0.06** **0.01** **0.08**
ECL τ/dark, Bhabha	Several combinations of cluster and energy (lmlxx)	1.28	**0.67 <- dominant**
gamma gamma	ECL3Dbhabha without track (ggsel)	0.04	**0.03**
Bhabha	ECL loose Bhabha (bhapur)	0.07	**0.05**
Other		-	**0.22**
Total L1		2.5	**2.5**

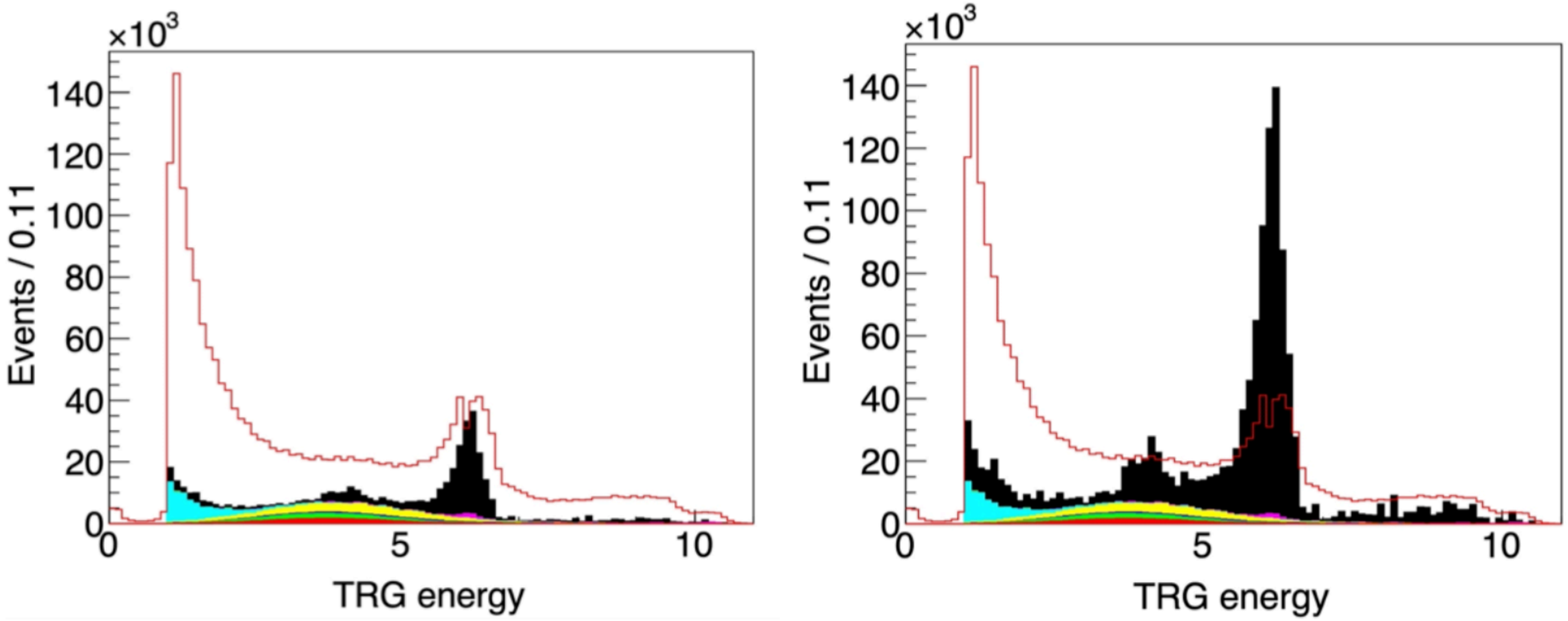
Physics process	Cross section [nb]	Selection Criteria	Reference
$\Upsilon(4S)$	1.110 ± 0.008	-	[2]
$u\bar{u}(\gamma)$	1.61	-	KKMC
$d\bar{d}(\gamma)$	0.40	-	KKMC
$s\bar{s}(\gamma)$	0.38	-	KKMC
$c\bar{c}(\gamma)$	1.30	-	KKMC
$e^+e^-(\gamma)$	300 ± 3 (MC stat.)	$10^\circ < \theta_e^* < 170^\circ$, $E_e^* > 0.15\,\text{GeV}$	BABAYAGA.NLO
$e^+e^-(\gamma)$	74.4	$p_e > 0.5\,\text{GeV}/c$ and e in ECL	-
$\gamma\gamma(\gamma)$	4.99 ± 0.05 (MC stat.)	$10^\circ < \theta_\gamma^* < 170^\circ$, $E_\gamma^* > 0.15\,\text{GeV}$	BABAYAGA.NLO
$\gamma\gamma(\gamma)$	3.30	$E_\gamma > 0.5\,\text{GeV}$ in ECL	-
$\mu^+\mu^-(\gamma)$	1.148	-	KKMC
$\mu^+\mu^-(\gamma)$	0.831	$p_\mu > 0.5\,\text{GeV}/c$ in CDC	-
$\mu^+\mu^-\gamma(\gamma)$	0.242	$p_\mu > 0.5\,\text{GeV}$ in CDC, $\geq 1\ \gamma\ (E_\gamma > 0.5\,\text{GeV})$ in ECL	-
$\tau^+\tau^-(\gamma)$	0.919	-	KKMC
$\nu\bar{\nu}(\gamma)$	0.25×10^{-3}	-	KKMC
$e^+e^-e^+e^-$	39.7 ± 0.1 (MC stat.)	$W_{\ell\ell} > 0.5\,\text{GeV}/c^2$	AAFH
$e^+e^-\mu^+\mu^-$	18.9 ± 0.1 (MC stat.)	$W_{\ell\ell} > 0.5\,\text{GeV}/c^2$	AAFH

Cross section of bhabha will increase to 1.23×10^5 nb if $0.5^\circ < \theta_e^* < 179.5^\circ$

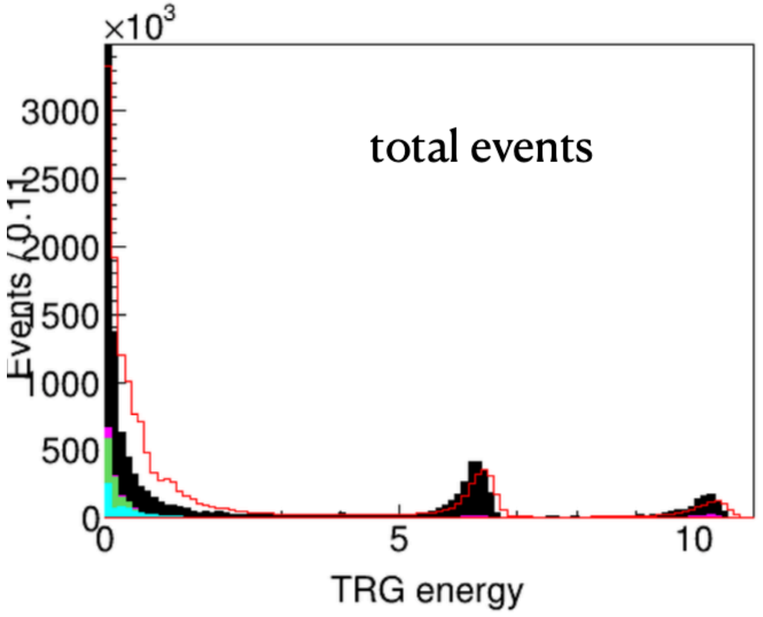
- **hie**: Basic ECL trigger. Requires sum of trigger towers >1GeV, with 100 MeV threshold per tower.
  - tower ≈ 4×4 crystals.
  - sum is over θ_{ID}^{L1} range [2,15]
  - Bhabha veto

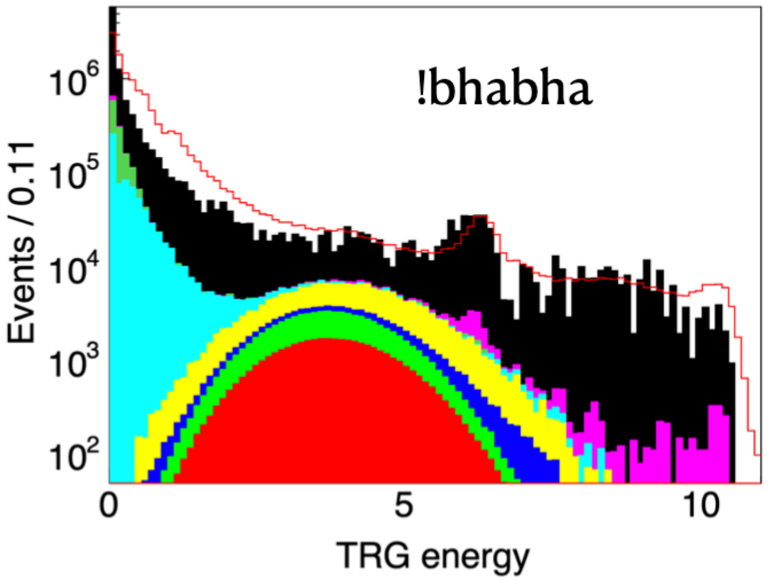


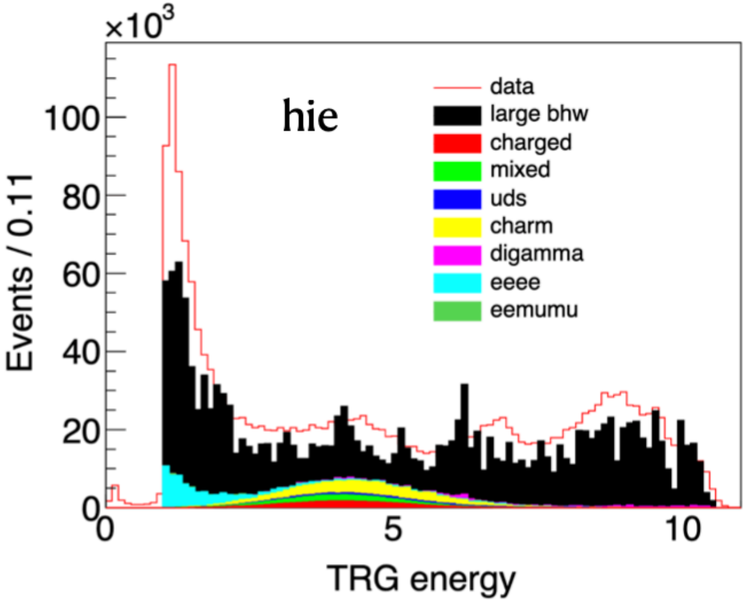
Total deposit energy from TRGECL (full detector range)



- Generate bhabha with babayaga_NLO, scattering angle are [10, 170] (left) and [0.5, 179.5] (right)
- Normalized with cross section.
- The default babayaga_NLO could not describe the small angle bhabha scattering...



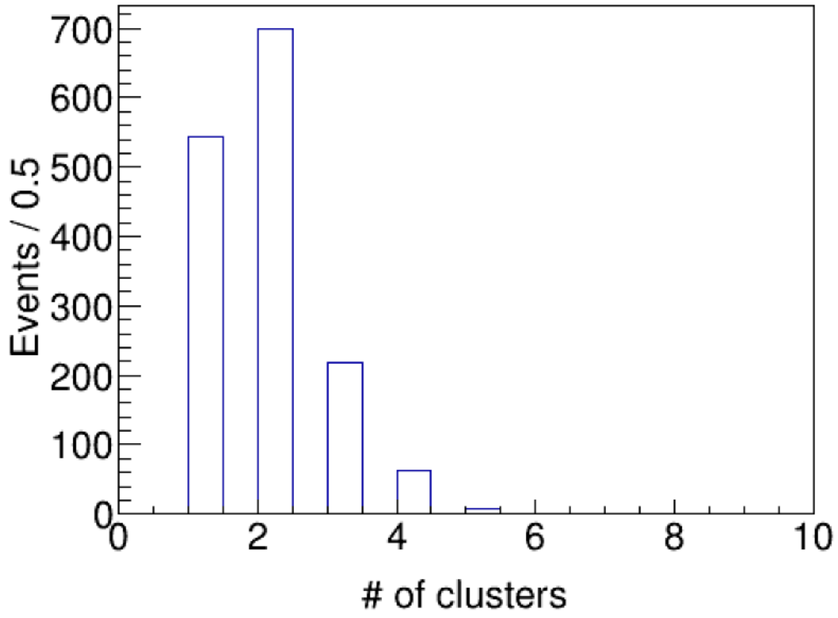


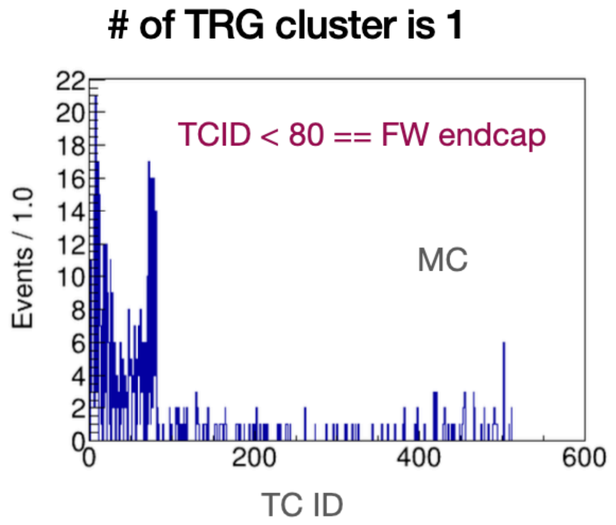


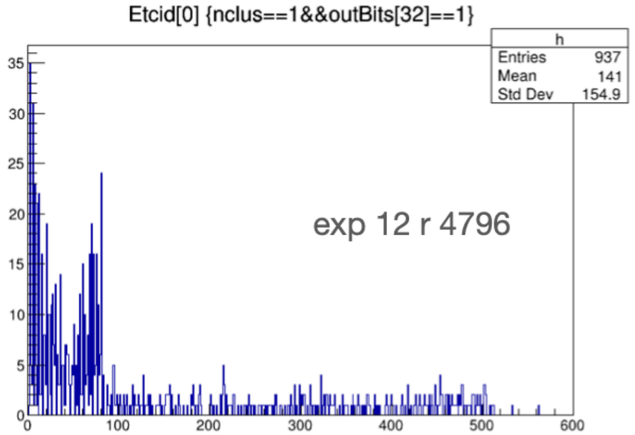
Generator settings:

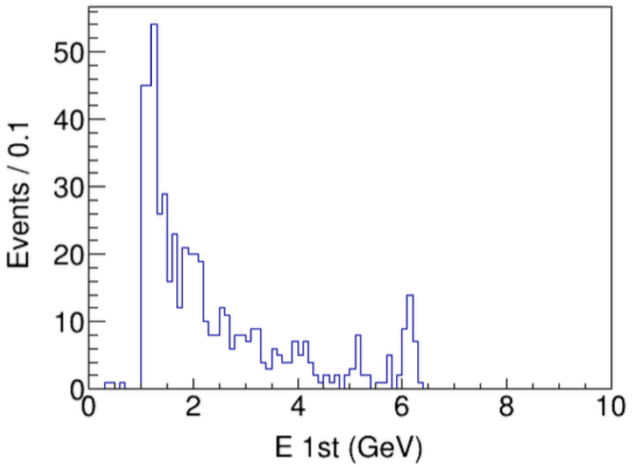
```
main.add_module("BHWideInput", ScatteringAngleRangeElectron=[0.5, 179.5],
                ScatteringAngleRangePositron=[0.5, 179.5])
add_cut("both tracks at least 1 degree", 2, 2, 1)
add_cut("at least one 10 degree", 1, 2, 10)
```

Change the generator from babayaga to BHWide.
MC now fit the data well.



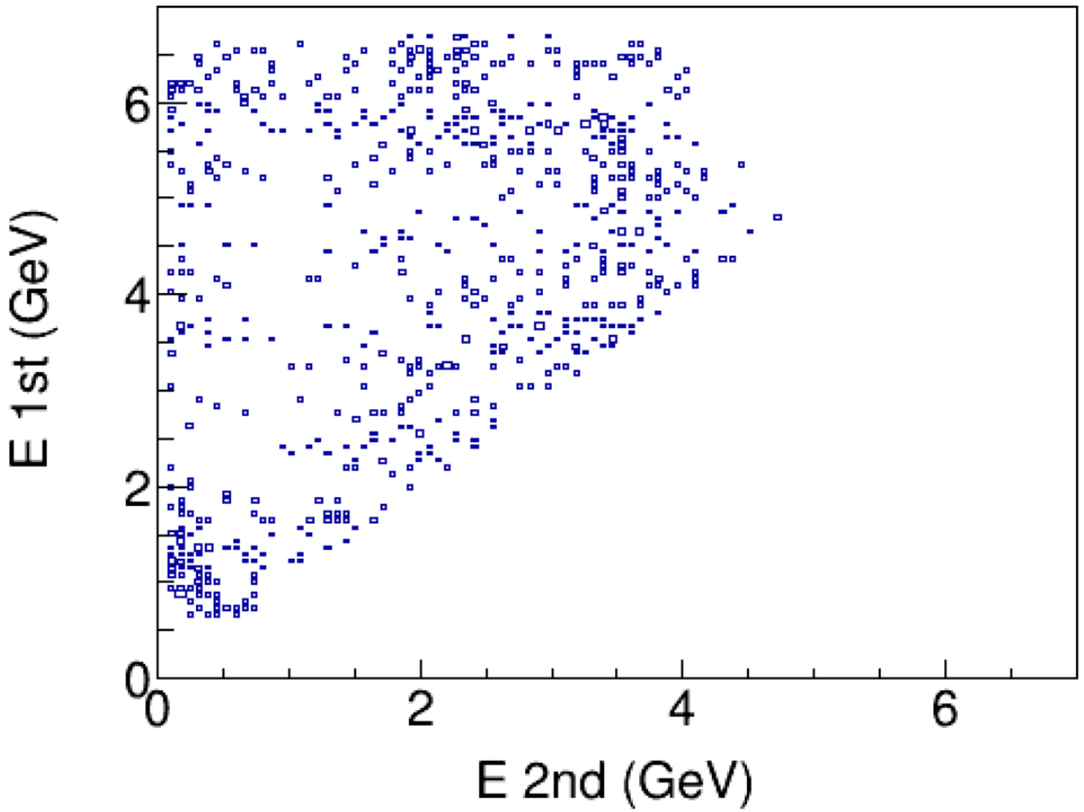


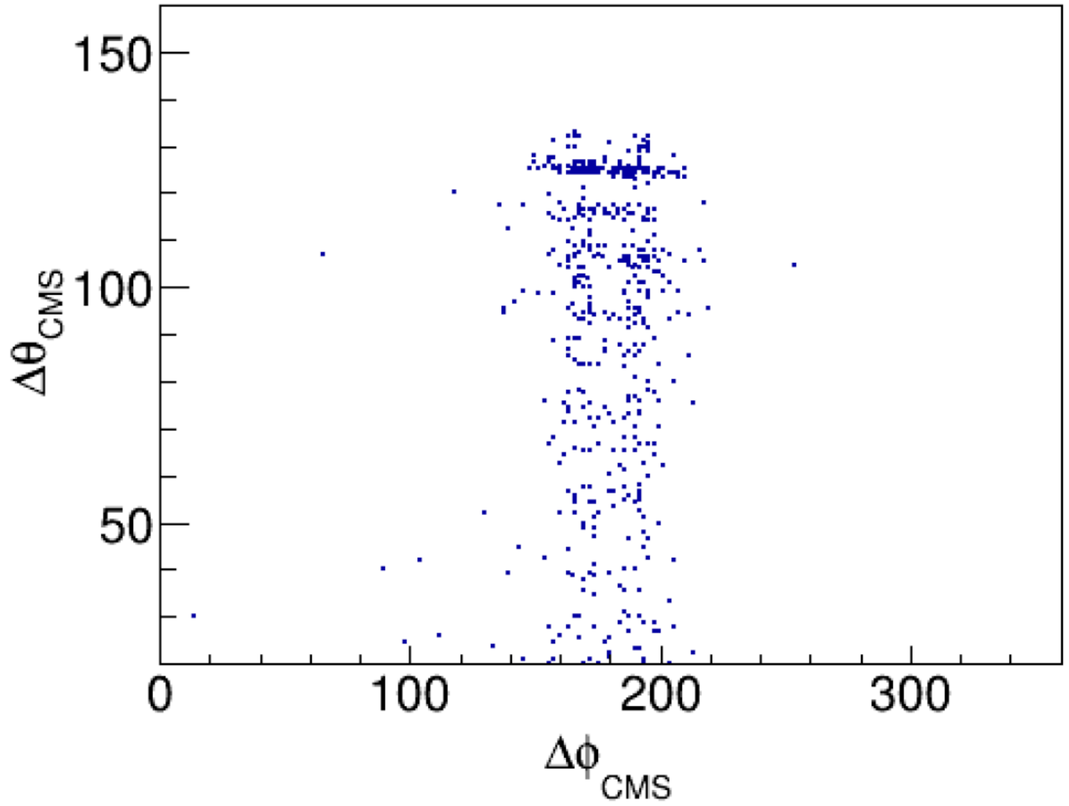




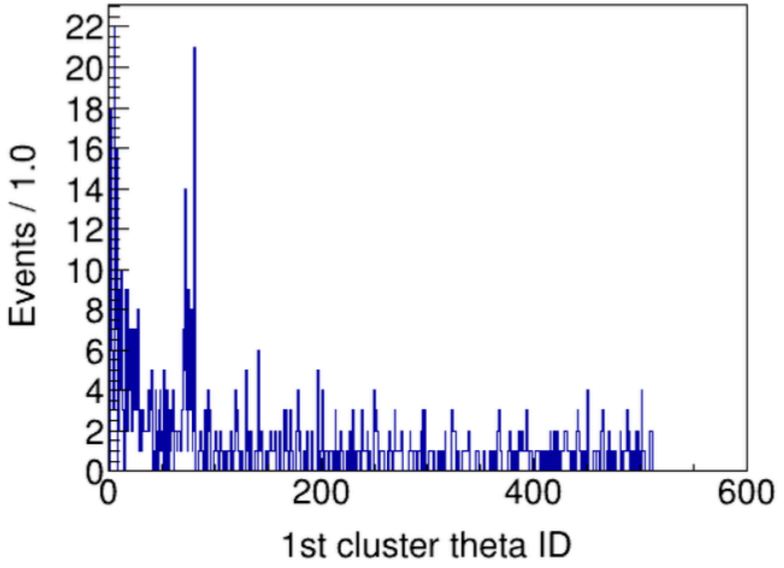
removing FW endcap cluster when # of cluster is only one

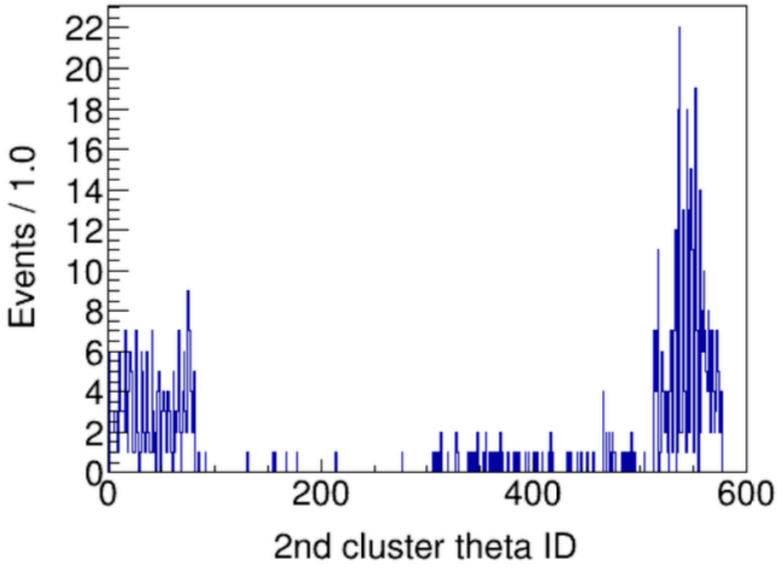
of TRG clusters is 2

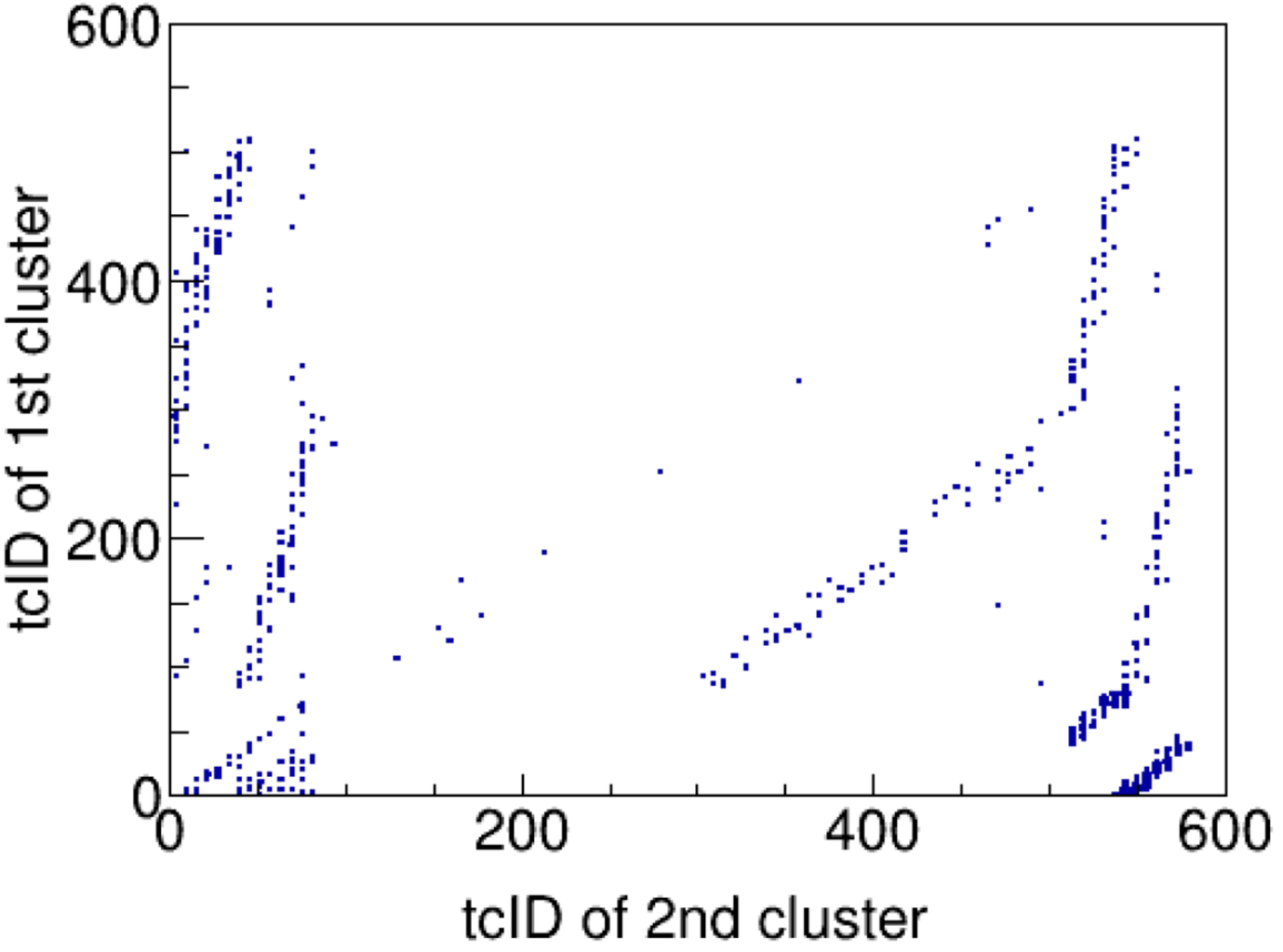




opening angle is smaller than bhabha veto requirement.







Most of the first energetic cluster is on FW endcap but still some on barrel.
Almost all second clusters are on endcap.

newhie = hie && 1-cluster-veto && 2-clusters-veto

1-cluster-veto: !(ncluster = 1 && tcid <= 80) FW endcap

but we have several different proposals for 2-cluster veto…

case I

2-cluster-veto: !(ncluster = 2 && $\Delta\theta_{\rm cms} > 120$ && $\Delta\phi_{\rm cms} > 150$)

bit logics	bhabha	taupair	eeee	data
hie	1531	735879	2628	2950
fff|ffo|c4|hie	1601	856847	3506	4476
newhie	937	730233	2331	2100
fff|ffo|c4|newhie	1007	851252	3210	3630

case II

2-cluster-veto: !(ncluster = 2 && $\Delta\theta_{\rm cms} > 120$ || $\Delta\phi_{\rm cms} > 150$)

newhie	354	474811	1297	1051
fff|ffo|c4|newhie	562	802404	2507	2857

case III

BW endcap FW endcap

2-cluster-veto: !(ncluster = 2 && ($\mathrm{tcid}_{\rm 2nd} \geq 500$ || $\mathrm{tcid}_{\rm 2nd} \leq 80$))

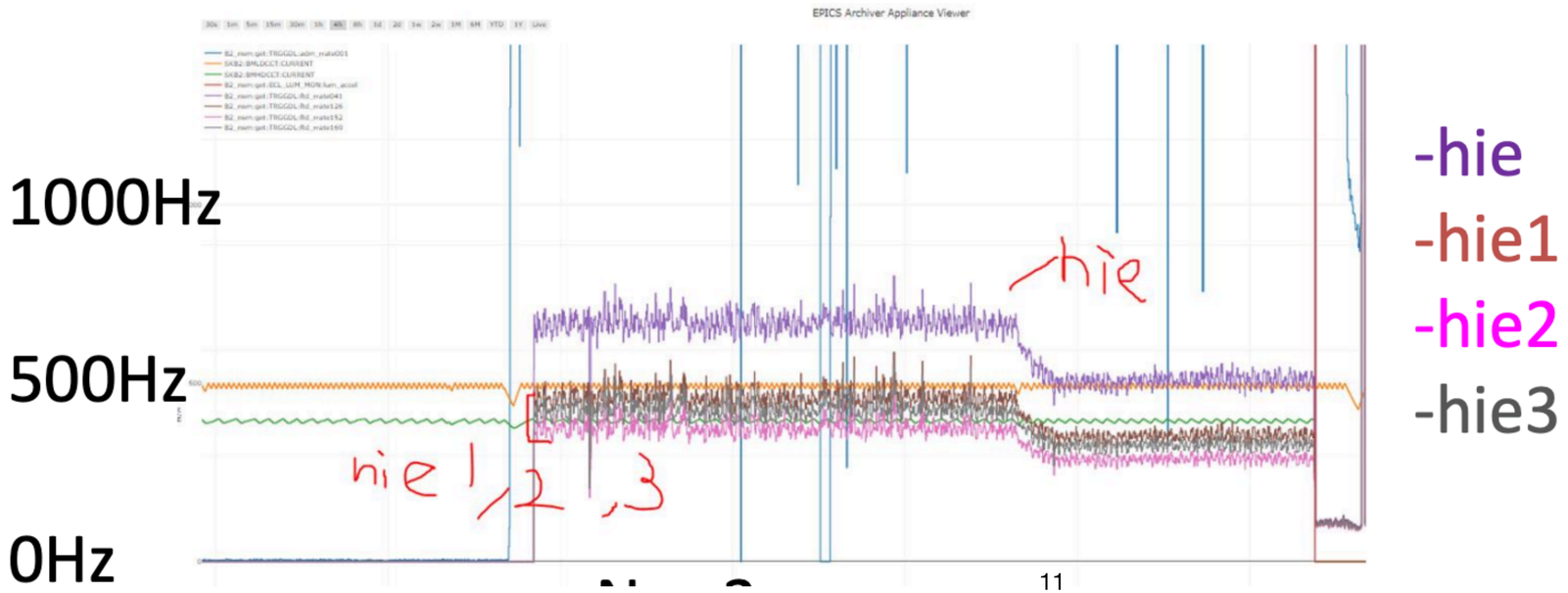
newhie	510	695997	1173	1640
fff|ffo|c4|newhie	558	823458	2165	3185

For a bhabha scattering event, the second energetic cluster is very likely to be the radiative photon

90	hie w/ additional Bhabha veto 1	**hie1**	• New hie to reduce Bhabha contribution(condition-1)
			• hie && 1CL veto && 2CL veto
			  • 1CL veto = not (N(CL)=1 && θ_{CM} in FW)
			  • 2CL veto = not (N(CL)=2 && 160°< $\Sigma\theta_{CM}$ < 200° && 150°< $\Delta\phi_{CM}$ < 250°)
			• See (link) for details
			• BIITRG-30 - Performance evaluation and optimization of new bhabha veto TO DO

91	hie w/ additional Bhabha veto 2	**hie2**	• New hie to reduce Bhabha contribution(condition-2)
			• hie && 1CL veto && 2CL veto
			  • 1CL veto = not (N(CL)=1 && θ_{CM} in FW)
			  • 2CL veto = not (N(CL)=2 && 160°< $\Sigma\theta_{CM}$ < 200° || 150°< $\Delta\phi_{CM}$ < 250°)
			• See (link) for details
			• BIITRG-30 - Performance evaluation and optimization of new bhabha veto TO DO

92	hie w/ additional Bhabha veto 3	**hie3**	• New hie to reduce Bhabha contribution(condition-3)
			• hie && 1CL veto && 2CL veto
			  • 1CL veto = not (N(CL)=1 && θ_{CM} in FW)
			  • 2CL veto = not (N(CL)=2 && CL_{LowerE} in FW or BW)
			• See (link) for details
			• BIITRG-30 - Performance evaluation and optimization of new bhabha veto TO DO



stt: CDC triggers

Number of neuro 3D track with p>0.7 GeV/c > 0

!bhabha_3D

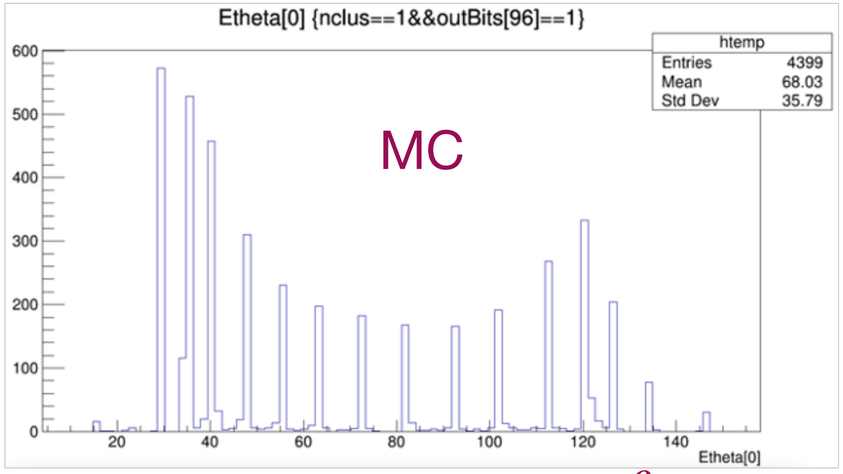
!veto

		MC	Run 1800	Run 1780	Run 1780 HLT
Nevts	total	358421	881163	19939728	2800098
	stt	10365	323314	4698662	945197
	stt&&nclus==1	4399	25116	2134753	103477
	stt&&nclus==2	4033	143461	1694201	406439
TRG rate	stt	214.69Hz	193.25Hz	1706.74Hz	343.33Hz
	stt&&nclus==1	83.53Hz	15.01Hz	775.43Hz	37.59Hz
	stt&&nclus==2	83.45Hz	85.75Hz	615.4Hz	147.63Hz

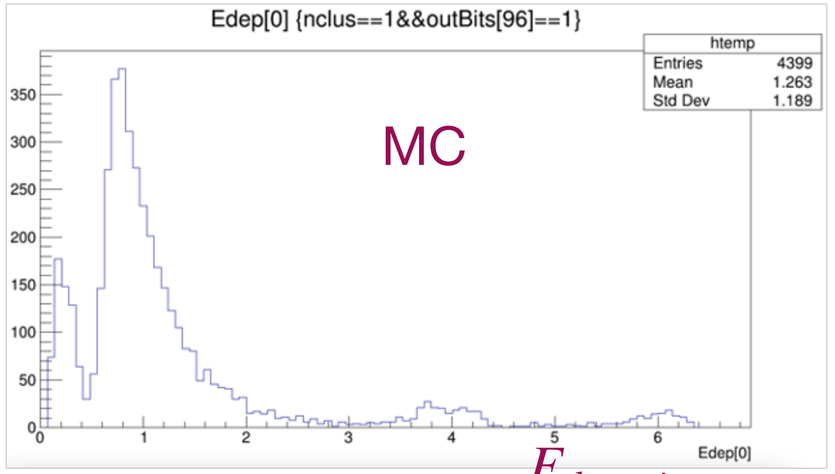
From bhabha MC: ~40% of stt events have only 1 cluster, and ~40% have 2 clusters

TRG rate of MC is estimated with the luminosity from run1780.

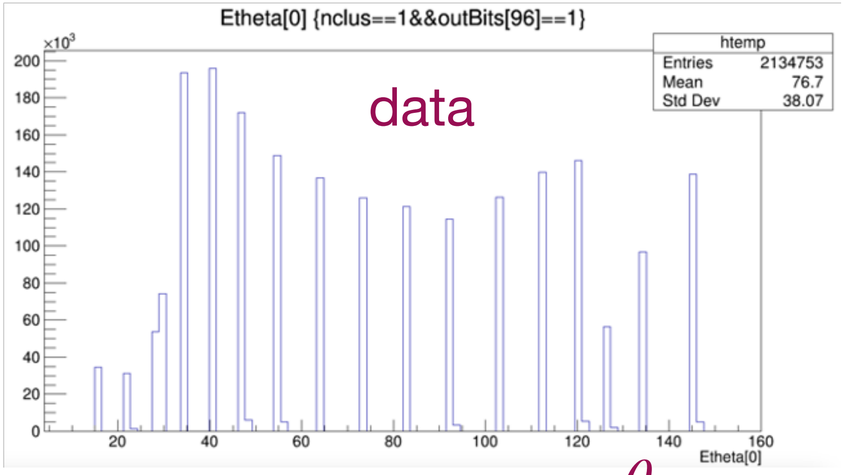
For one-cluster event



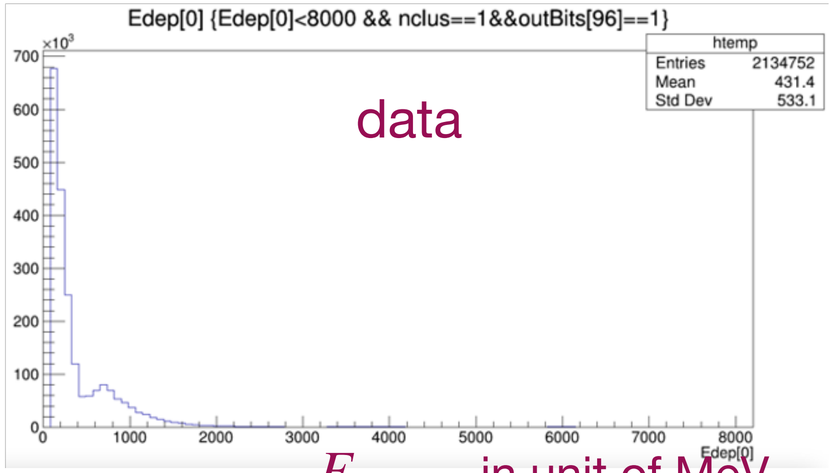
θ_{lab}



$E_{deposit}$



θ_{lab}

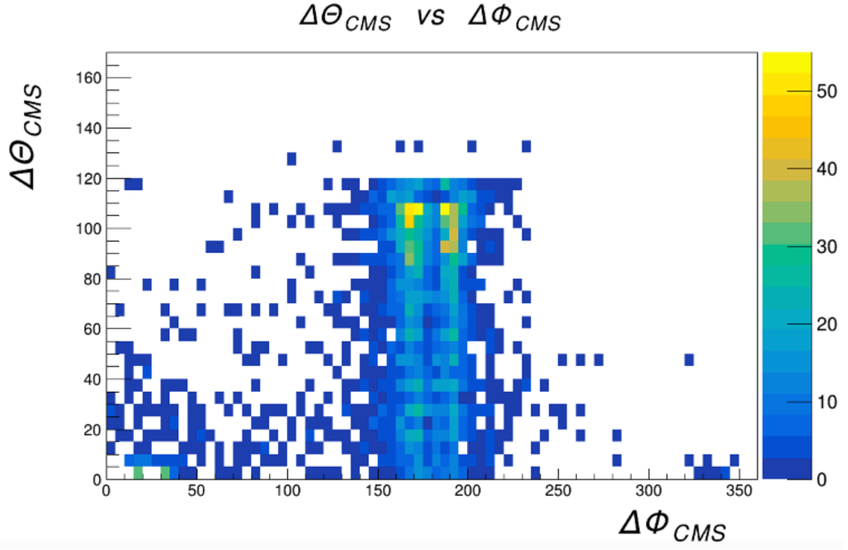


$E_{deposit}$ in unit of MeV

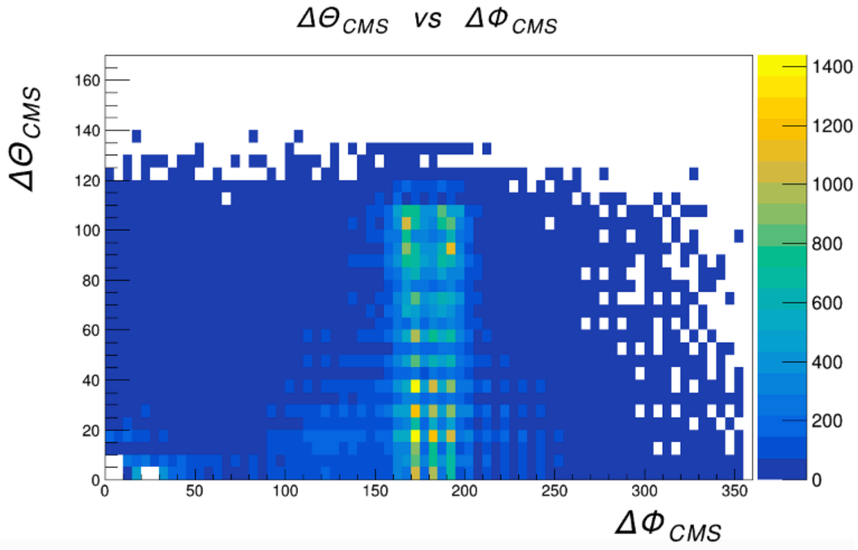
Clusters are mostly on barrel, coincident with the CDC region.
Radiative photon and one electron is missing

$\Delta\theta_{cms}:\Delta\phi_{cms}$ -Nclus==2 &&outBits[96]==1

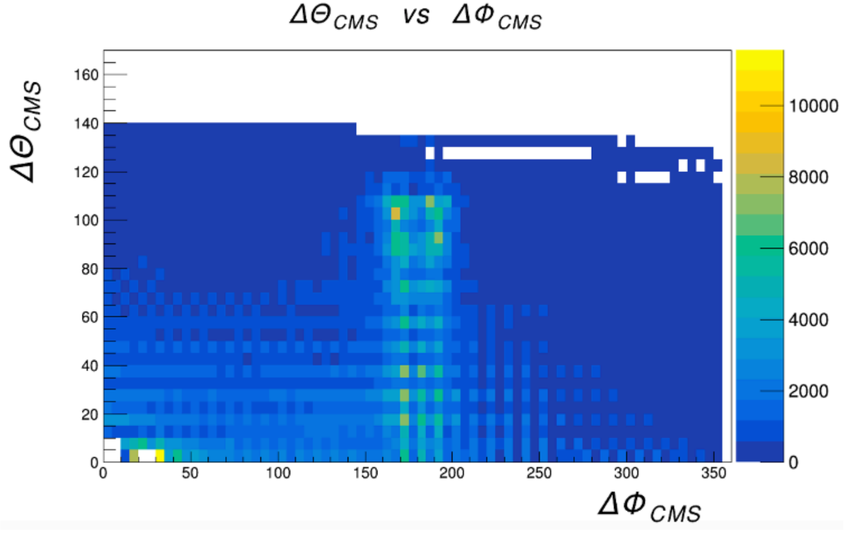
MC



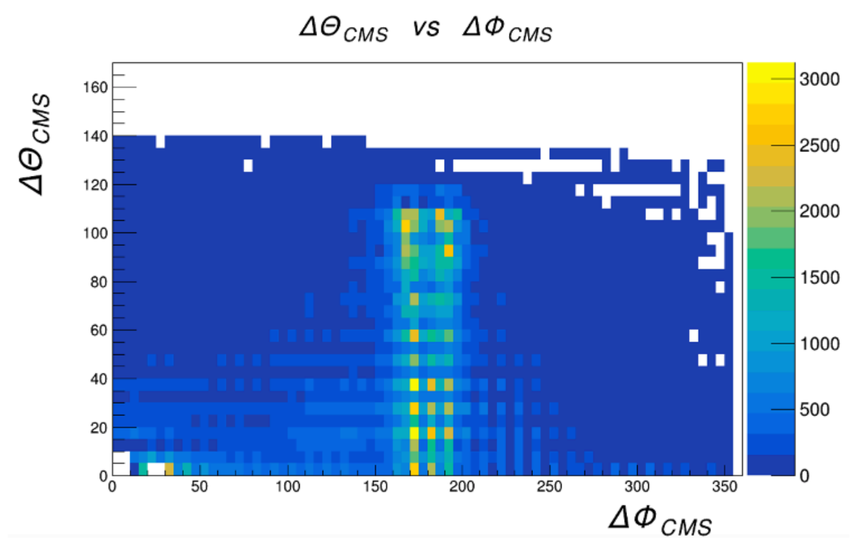
Run 1800



Run 1780



Run 1780 HLT



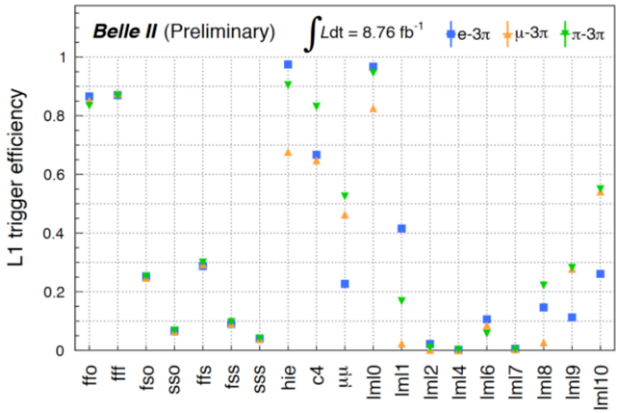
We tried same veto as we did in hie study

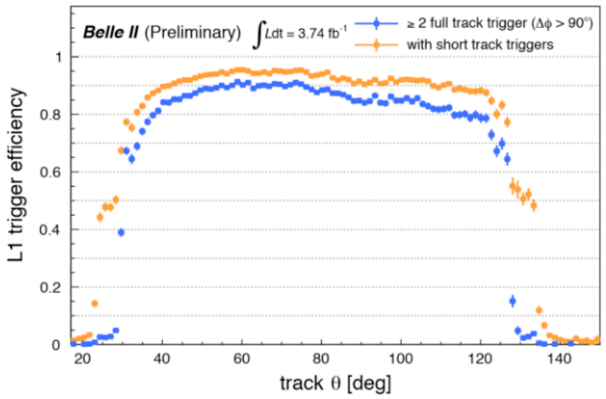
Name of cut	Definition	Index
stt	outBits[96]==1	a
1 cluster cut	!(ncluster = 1 && tcid <= 80°)	b
2 cluster cut (1)	!(ncluster = 2 && ($\Delta\theta$cms > 120° && $\Delta\phi$cms > 150°))	c
2 cluster cut (2)	!(ncluster = 2 && ($\Delta\theta$cms > 120° ‖ $\Delta\phi$cms > 150°))	d
2 cluster cut (3)	!(ncluster = 2 && (tcid2nd ≥ 500°‖tcid2nd ≤ 80°))	e
2 cluster cut (4)	!(ncluster = 2 && ($\Delta\theta$cms > 120°))	f
2 cluster cut (5)	!(ncluster = 2 && ($\Delta\phi$cms > 150°))	g
2 cluster cut (6)	!(ncluster = 2 &&((160°<Σ"θcms"<200°) && (150<$\Delta\phi$cms < 250)))	h
2 cluster cut (7)	!(ncluster = 2 &&((160°<Σ"θcms"<200°) ‖ (150°<$\Delta\phi$cms <250°))	i
2 cluster cut (8)	!(ncluster = 2 && (160°<Σ"θcms"<200°))	j
2 cluster cut (9)	!(ncluster = 2 && (150°<$\Delta\phi$cms < 250°))	k

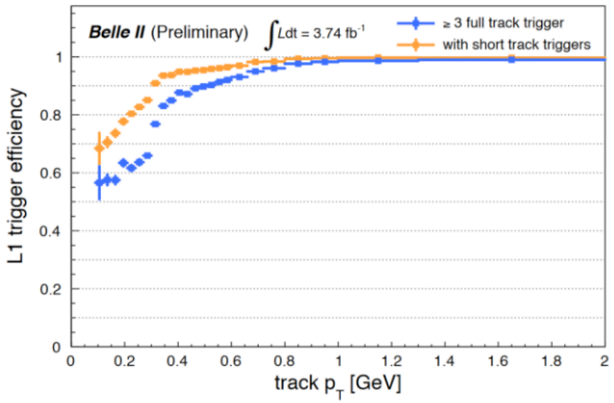
GetEntries	TRG rate	GetEntries	TRG rate
a	386.43Hz	a+k	268.14Hz
a+b	364.1Hz	a+b+c	363.95Hz
a+c	386.28Hz	a+b+d	188.02Hz
a+d	207.85Hz	a+b+e	256.17Hz
a+e	278.5Hz	a+b+f	363.88Hz
a+f	386.21Hz	a+b+g	244.95Hz
a+g	267.28Hz	a+b+h	302.03Hz
a+h	324.36Hz	a+b+i	183.69Hz
a+i	203.53Hz	a+b+j	294.49Hz
a+j	316.83Hz	a+b+k	246.8Hz
total		358421	

Requirement on $\Delta\phi$ is far more powerful than others
Need further study…

Bhabha veto in tau selection

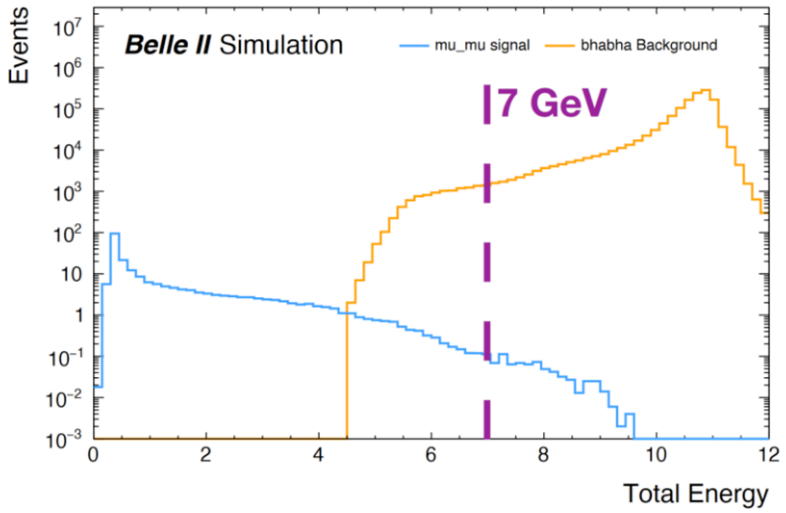


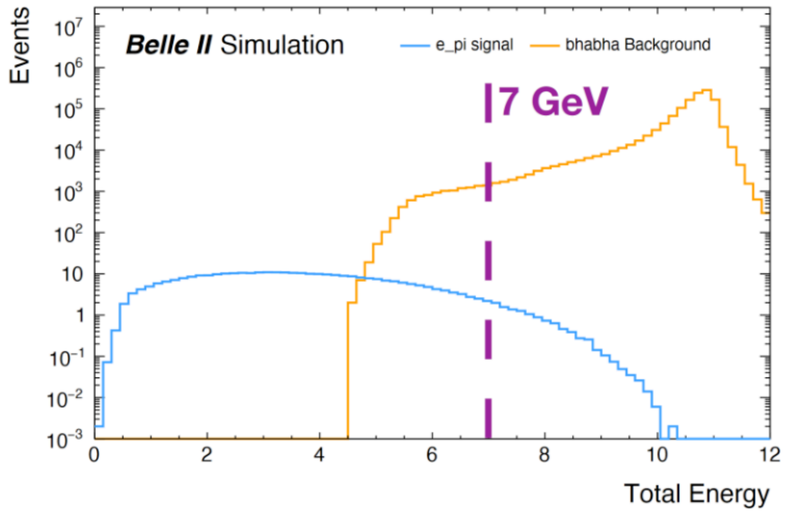




Overall trigger efficiency is acceptable

BUT: too many contamination from Bhabha





Preselections

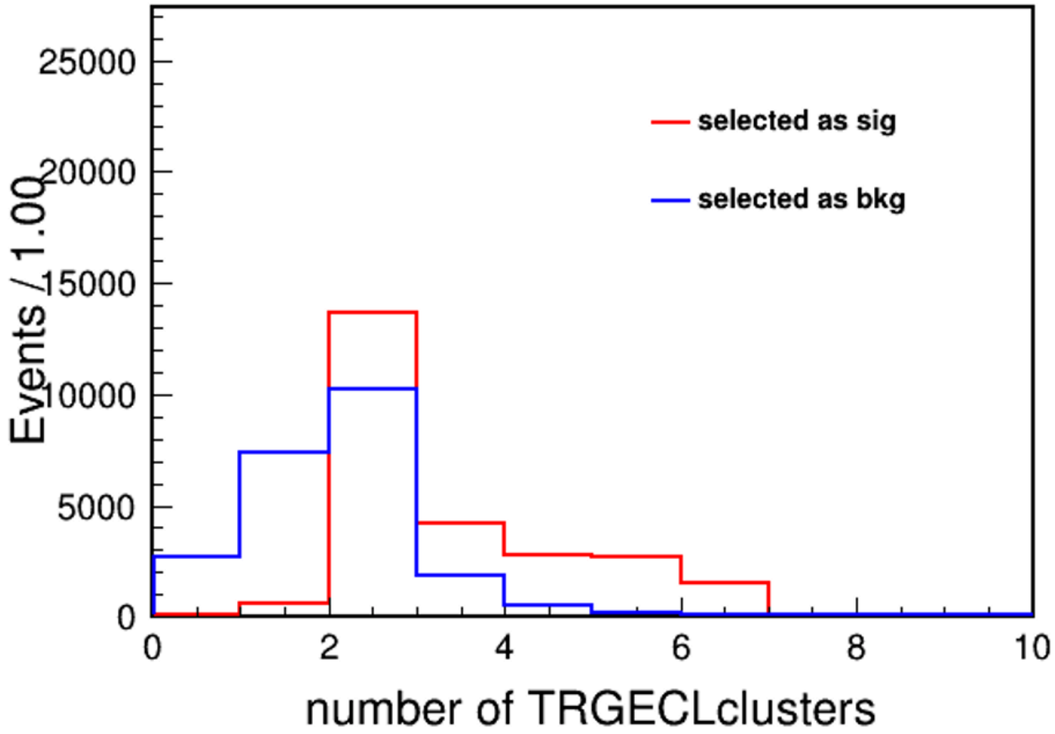
Select signal/background with offline selection criteria:

```
variables.addAlias('isbha', 'L1FTDL(bha3d)')

stdc.stdPi(listtype='all', path=main)
ma.cutAndCopyList('pi+:cool', 'pi+:all', cut='dr < 1.0 and dz < 3.0', path=main)
ma.buildEventShape(foxWolfram=True, cleoCones=False, jets=False, harmonicMoments=False,
                   allMoments=False, collisionAxis=False, sphericity=False, thrust=True, path=main)
ma.buildEventKinematics(path=main)
ma.reconstructDecay(decayString='tau+:sig1 -> pi+:cool', cut='', dmID=1, path=main)
ma.reconstructDecay(decayString='tau+:sig2 -> pi+:cool pi-:cool pi+:cool', cut='', dmID=2, path=main)
copyLists('tau+:sig', ['tau+:sig1', 'tau+:sig2'], path=main)
ma.reconstructDecay(decayString='vpho:sig -> tau+:sig tau-:sig',
                    cut='thrust > 0.85 and visibleEnergyOfEventCMS < 11.5 and  \
                         0.52<missingMomentumOfEventCMS_theta<2.8 and \
                         1<missingMass2OfEvent<49 and isbha!=1',
                    path=main)
```

If the number of vpho is not 0, tagged as signal, otherwise background.

Training --- FANN

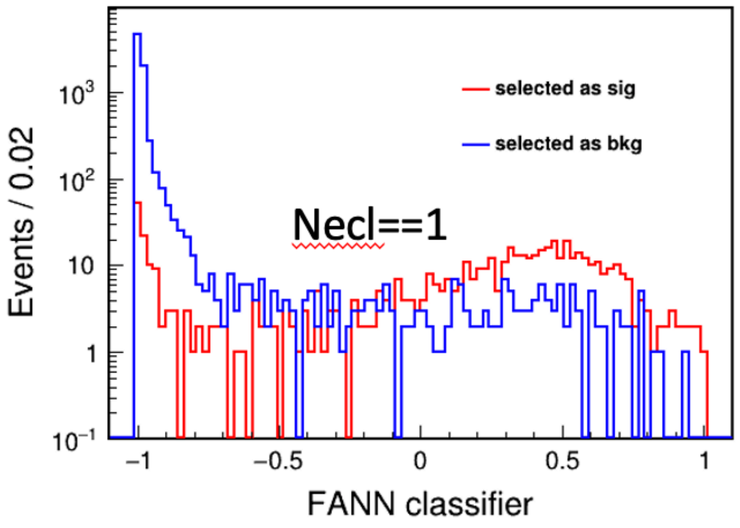


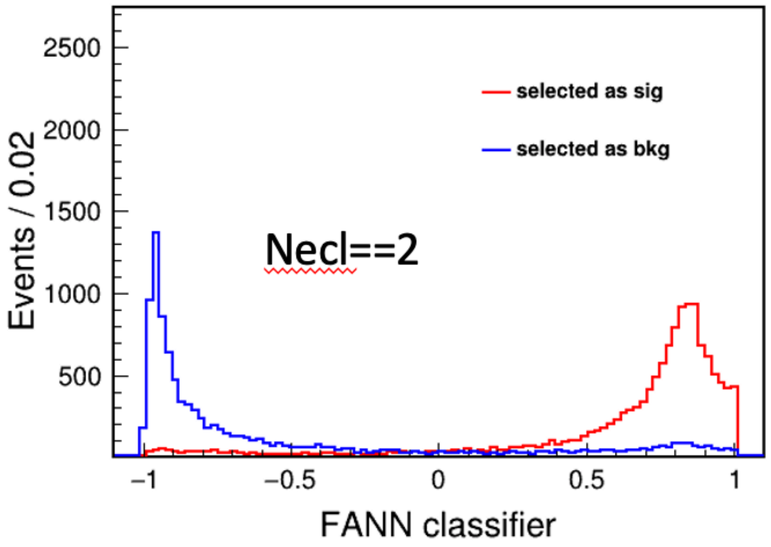
Variables:
Tracks: cdcf_0-35, cdcs_0-35, cdci_0-35
Clusters: necl, energy_0-5, theta_0-5, phi_0-5
(training breaks after adding cluster6,7, why? I don't know…)

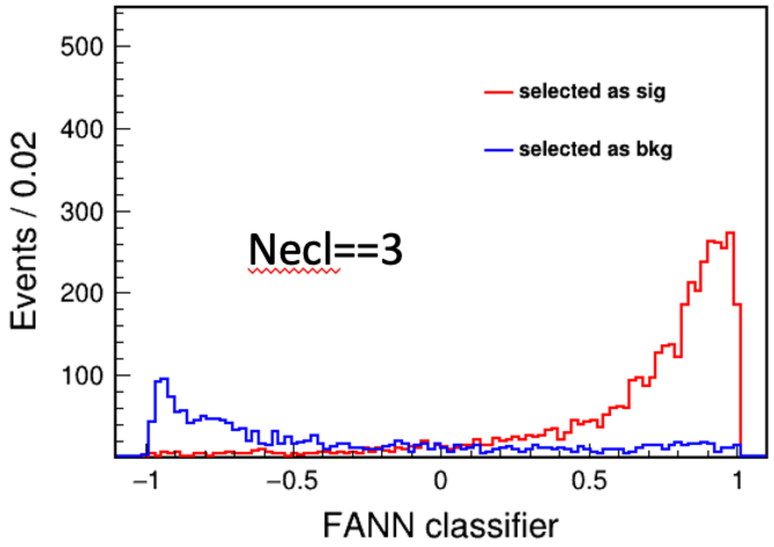
Hyper parameters:

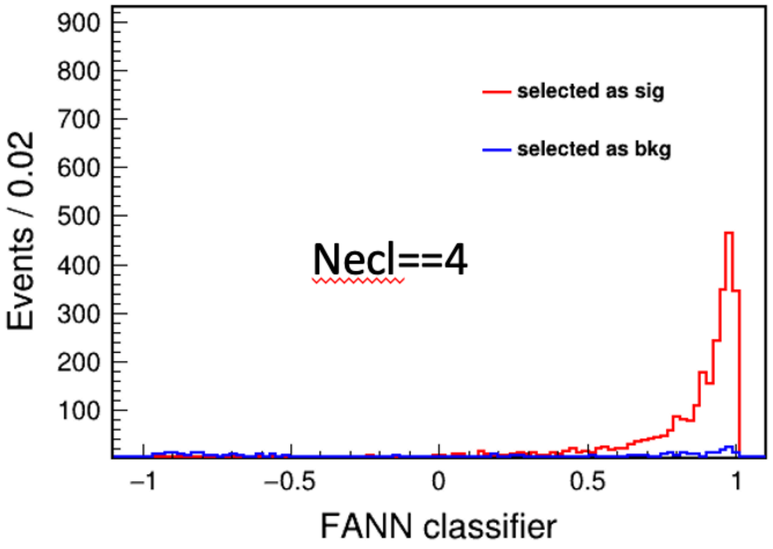
```
fann_options = basf2_mva.FANNOptions()
fann_options.m_number_of_threads = 1
fann_options.m_max_epochs = 100
fann_options.m_validation_fraction = 0.001
fann_options.m_test_rate =    fann_options.m_max_epochs + 1  # Never test
fann_options.m_hidden_layers_architecture = "1*100“ # one hidden layer with 100 nodes
fann_options.m_random_seeds = 1
```

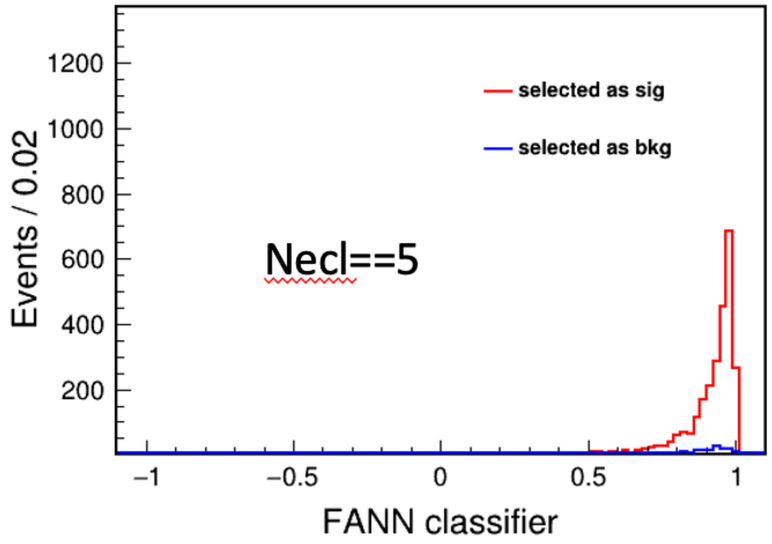
Train with run1780, test with run1779

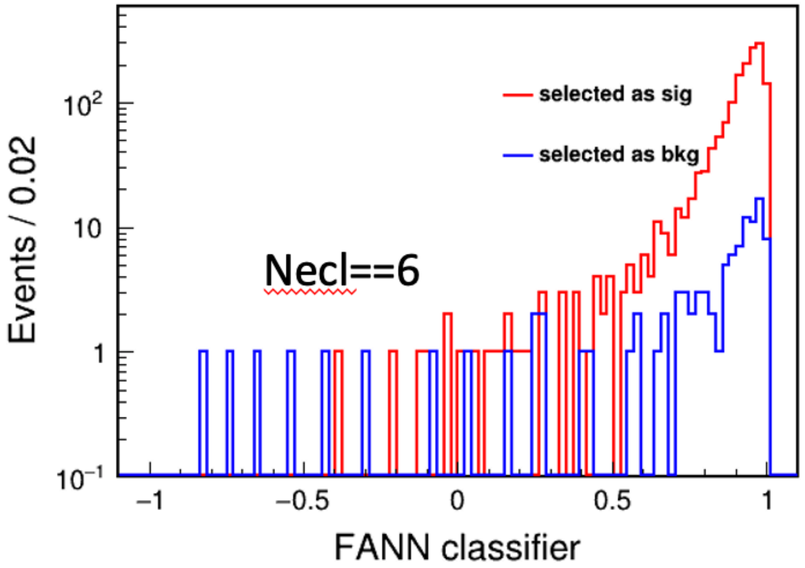






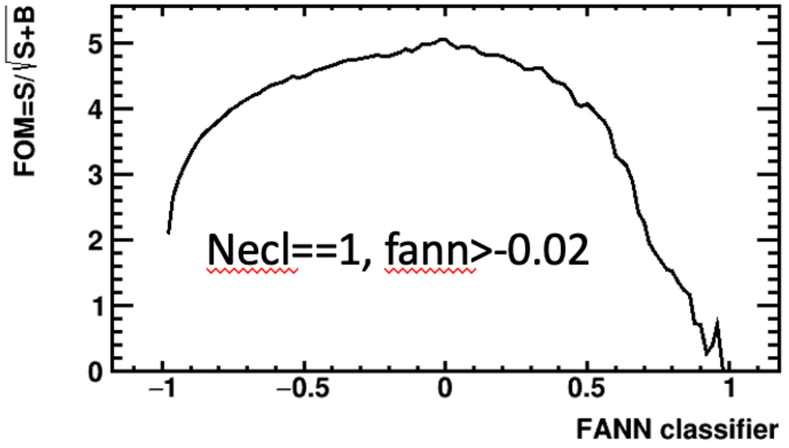


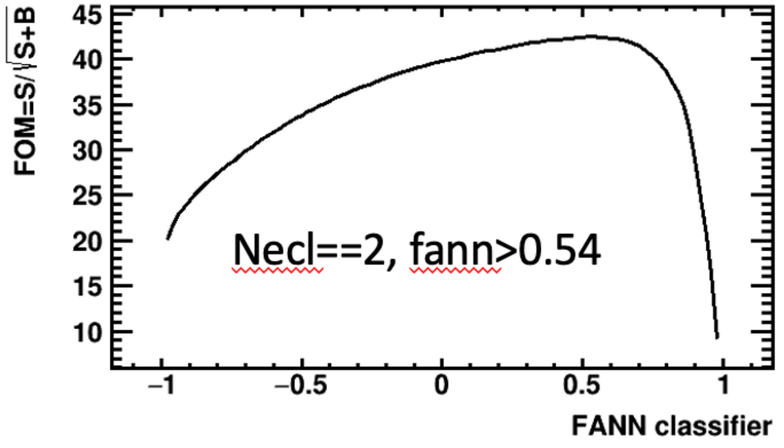


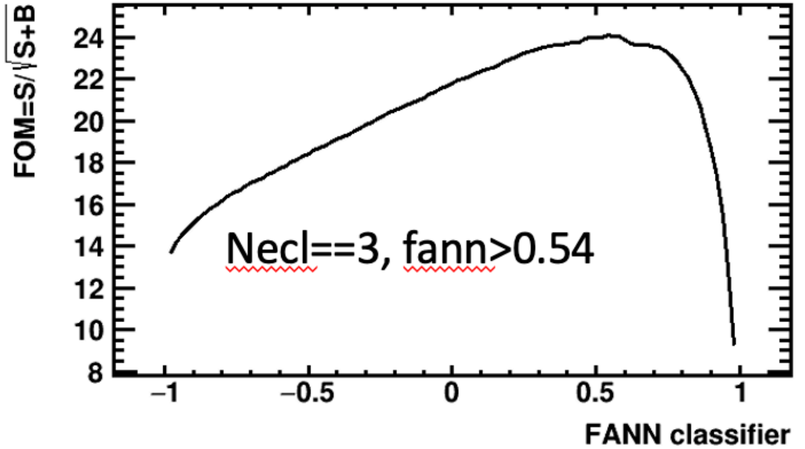


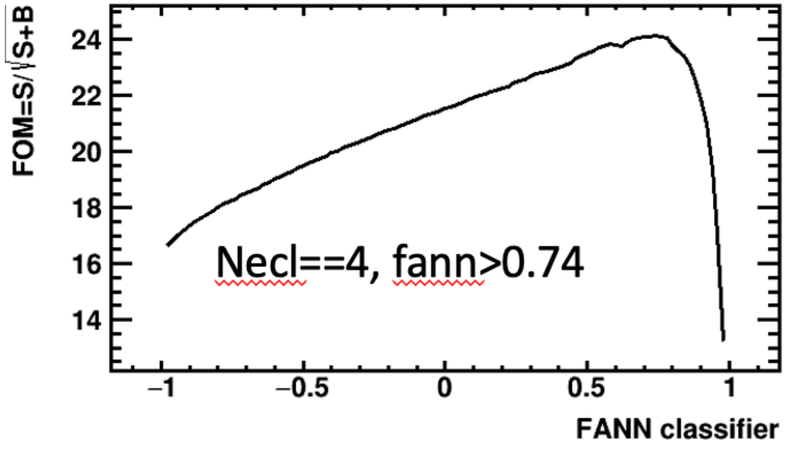
***Background is scaled with 1/50.

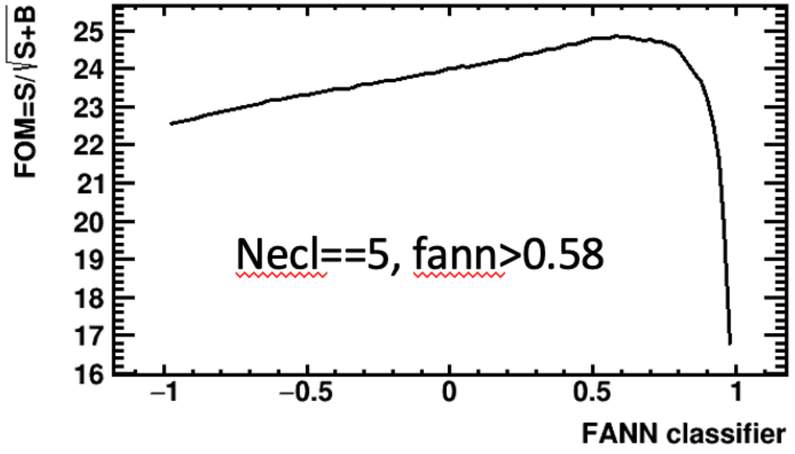
optimization

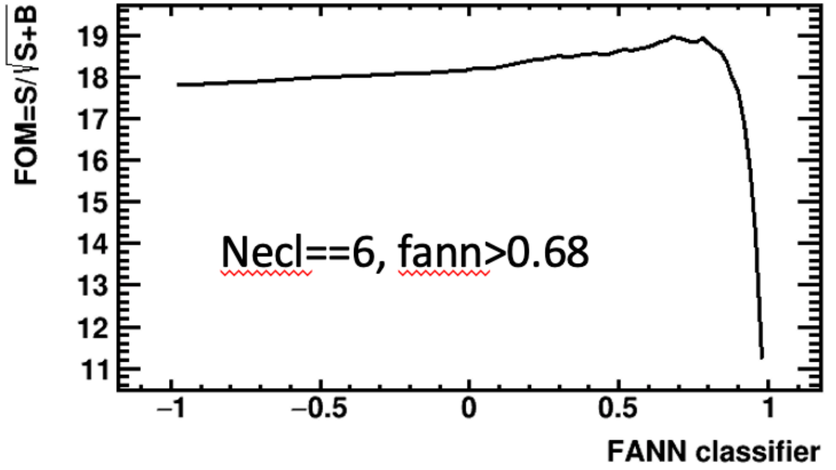












- # selected sig: number of signal events after preselection
- # selected bkg: number of signal events after preselection
- #identified sig: number of events with MVA requirement > {value}
- #identified bkg: number of events with MVA requirement < {value}
- # wrong signal: number of background events with MVA requirement > {value}
- Purity = 1 – wrong signal / identified signal
- Selection rate = identified signal – wrong signal / selected signal
- Rejection rate = identified bkg / total events

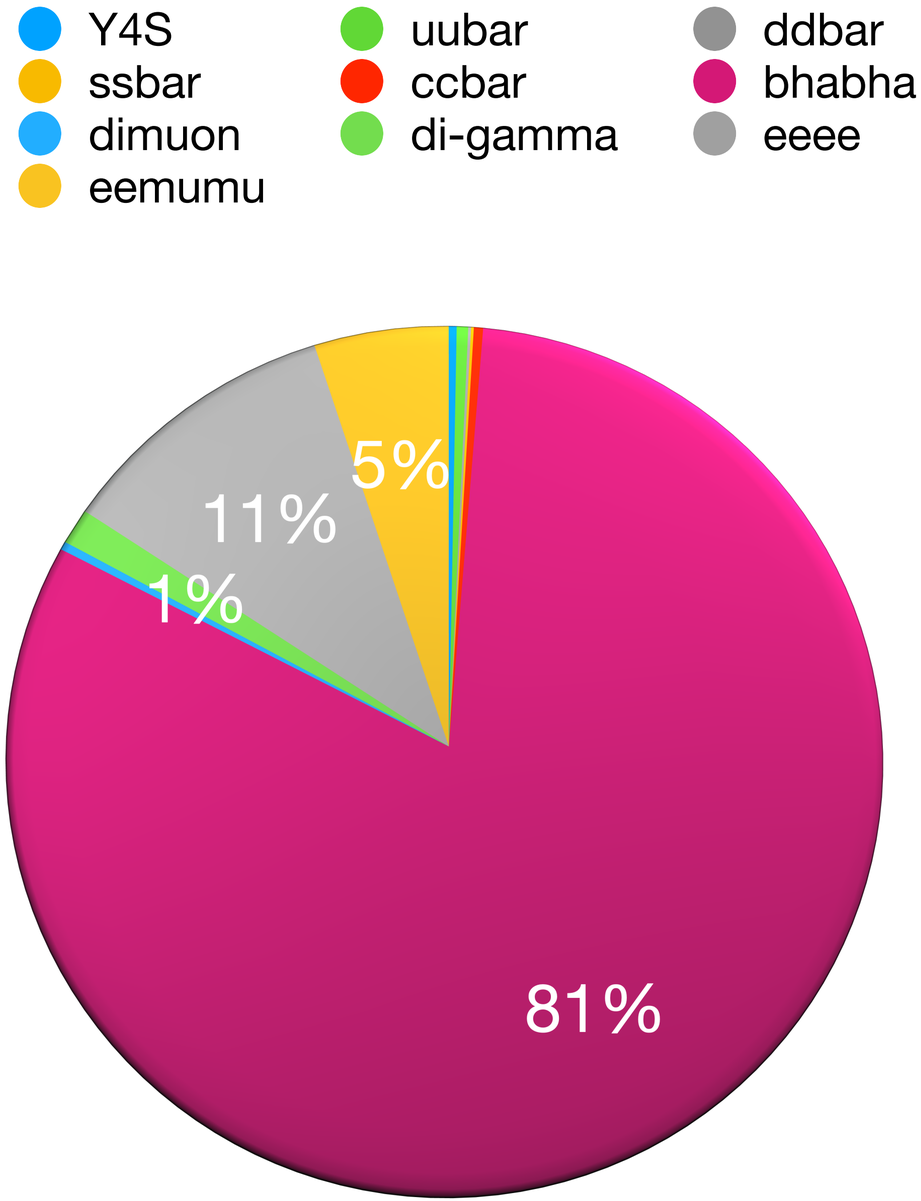
N clusters	# selected sig	# selected bkg	#identified sig	# wrong signal	purity	Selection rate	Rejection rate
0	6	132869	0	0	-	-	100.0%
1	571	364008	5593	5214	6.78%	66.37%	98.47%
2	13691	502212	65951	55047	16.53%	79.64%	87.22%
3	4194	92835	18613	15329	17.64%	78.30%	80.82%
4	2823	26152	8351	6146	26.40%	87.11%	71.18%
5	2698	11606	10358	7829	24.42%	93.74%	27.59%
6	1520	5760	5599	1481	25.33%	93.29%	23.09%

Compare with different tau triggers:

N clusters	#identified sig	# of taub2b	# of taub2b2
0	0	140	9
1	5593	2002	538
2	65951	171709	62391
3	18613	38206	14578
4	8351	16483	8512
5	10358	10918	7456
6	5599	5500	3674

Summary

- We studied the bhabha events in hie/stt/tau triggers.
  - We plan to use new hie definition instead of old one.
  - Study on stt is ongoing. The new bhabha veto (used in hie) seems not effective in stt case
    - Will veto on $\Delta\phi$ affect other physics processes?
  - Bhabha veto based on neuro in tau triggers is ongoing.
    - Improve signal/background separation


Y4S
uubar
ddbar
ssbar
ccbar
bhabha
dimuon
di-gamma
eeee
eemumu
5%
11%
1%
81%