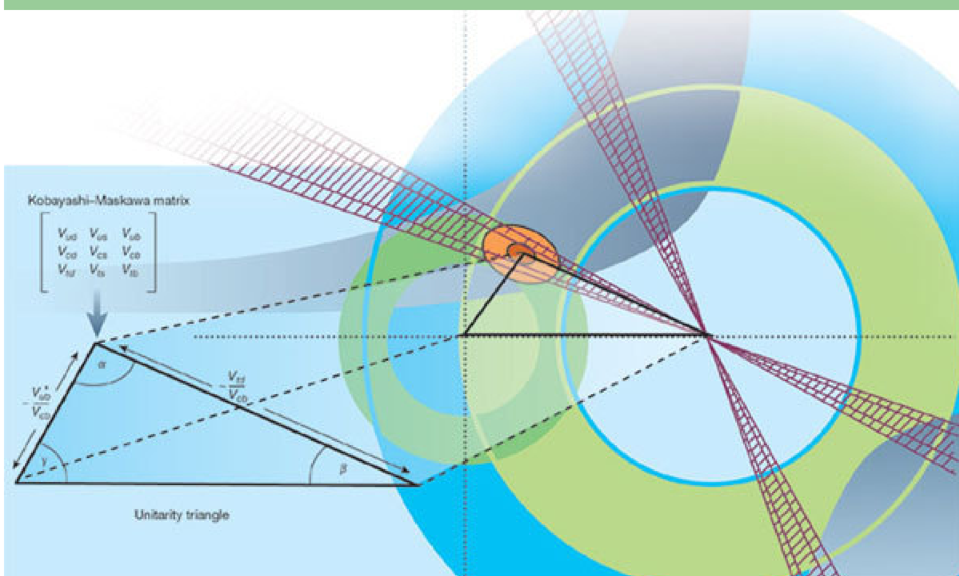
Flavor tagging – status & prospects



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Tools Workshop

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History

Name	Type	Nr of cat.'s	Q
Elba	cut-based + Neural Net	4	25.0(8)%
Moriond	Neural Net	4	29.3(6)%
Tag04	Neural Net	6	30.5(4)%
Belle	Lookup table	6	28.8(6)%

	Run 1-4 (PRL)		
	Eff.	ω	Q
Lepton	0.086(1)	0.032(8)	0.075(2)
Kaon I	0.109(1)	0.046(7)	0.090(2)
Kaon II	0.171(2)	0.156(6)	0.081(2)
KaonPion	0.137(1)	0.237(7)	0.038(2)
Pions	0.145(1)	0.330(7)	0.017(1)
Other	0.100(1)	0.441(8)	0.003(1)
Total			**0.305(4)**

Documentation

BADs:

BAD 242 : User guide on tagging tools
BAD 317 : Moriond tagger
BAD 729 : detailed description of Tag04
BAD 1025 : NIM paper draft – in preparation

Webpage with recipes, documentation, links to talks, etc.:

http://www.slac.stanford.edu/BFROOT/www/Physics/Tools/Tagging/Main/index.html

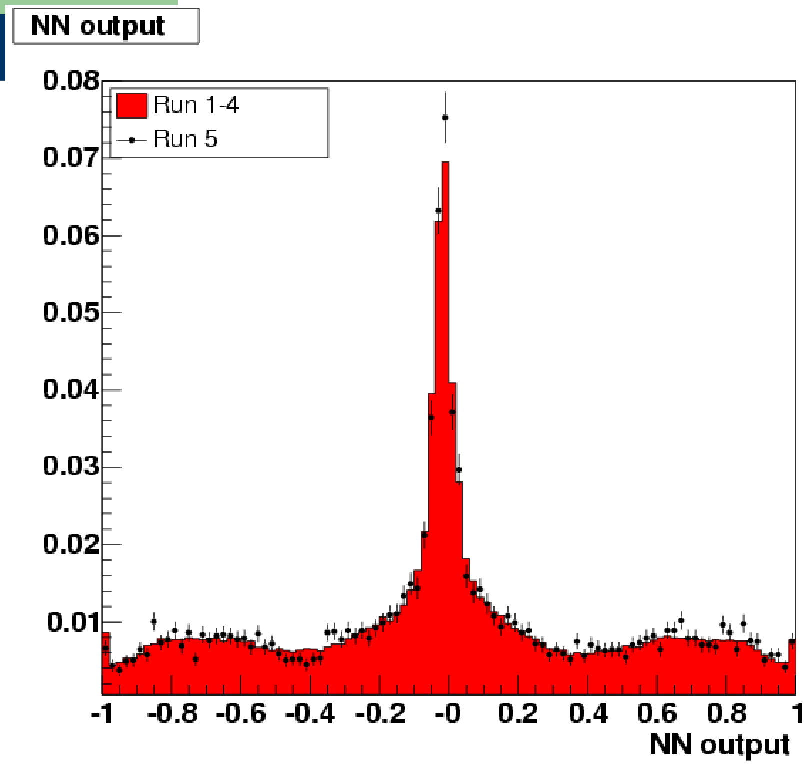
Current activities

Re-write of NN training/testing package BtgTest (done)
- based on PERL + ROOT macros
- retraining and testing made easier for us

Efforts to (further) improve tagging performance:
- adding new inputs, composites – not fruitful so far
- changing network architecture – not fruitful so far
- different types of classifiers (→ see Ilya's talk)
- improved training methods
- note: do not expect much higher Q's in the future anymore…

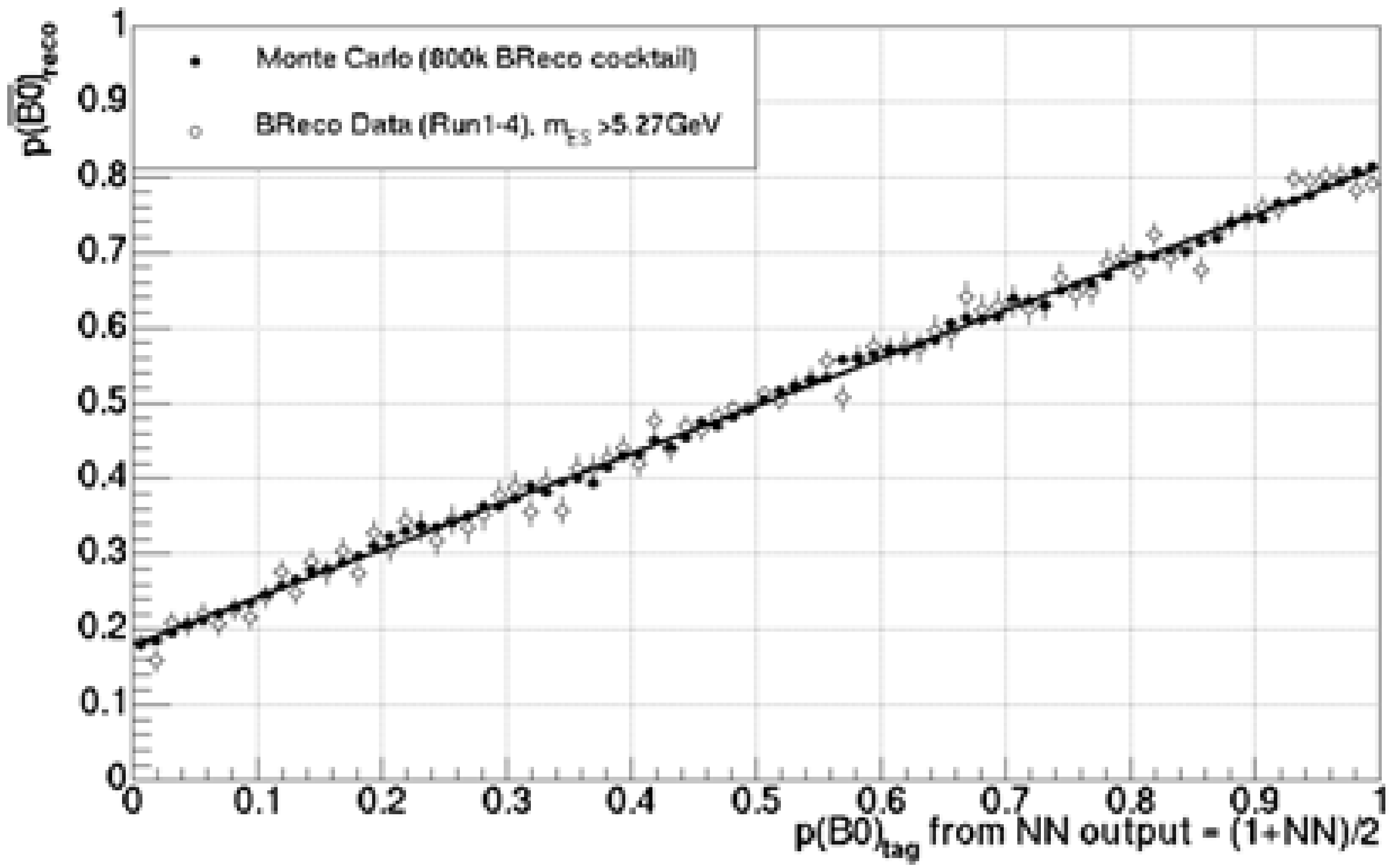
Validation:
- R18 validation
- Run 5 validation
- Note: tagging parameters (ω,$\Delta\omega$,eff,Q) are specific to data set and release
  - e.g. expect more muon tags with LST
  - we expect benefits from higher track reconstruction eff in R18
  - we will provide tagging parameters on standardized data sets

Run 5 tagging performance

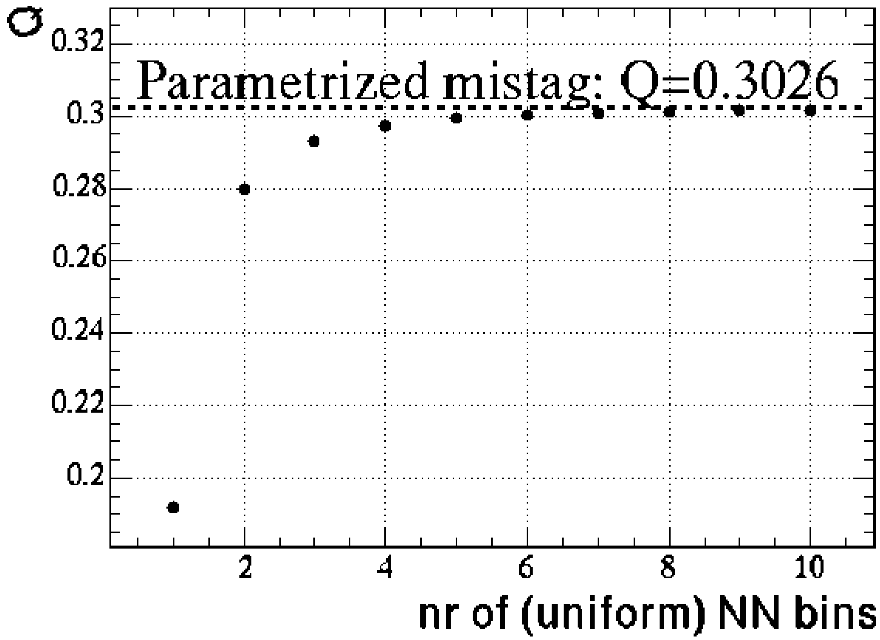


	Run 1-4 (PRL)			Run 5 so far		
	Eff.	ω	Q	Eff.	ω	Q
Lepton	0.086(1)	0.032(8)	0.075(2)	0.069(27)	0.056(42)	0.054(24)
Kaon I	0.109(1)	0.046(7)	0.090(2)	0.113(23)	0.061(36)	0.087(23)
Kaon II	0.171(2)	0.156(6)	0.081(2)	0.170(20)	0.112(32)	0.102(21)
KaonPion	0.137(1)	0.237(7)	0.038(2)	0.128(25)	0.267(32)	0.028(11)
Pions	0.145(1)	0.330(7)	0.017(1)	0.147(24)	0.304(39)	0.023(10)
Other	0.100(1)	0.441(8)	0.003(1)	0.102(30)	0.467(48)	0.000(1)
Total			**0.305(4)**			**0.29(4)**

Parametrizing mistag rates



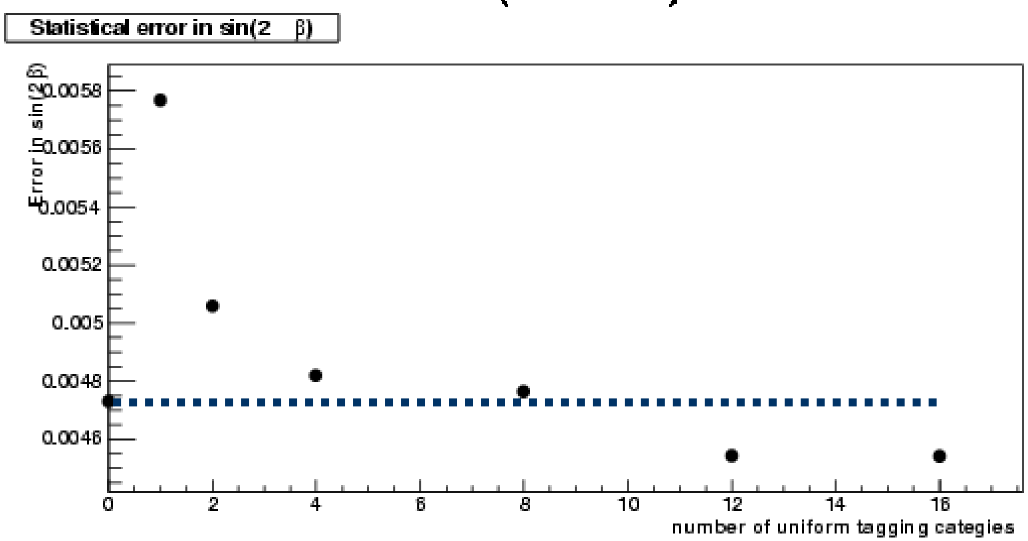
ω(NN) – statistical precision



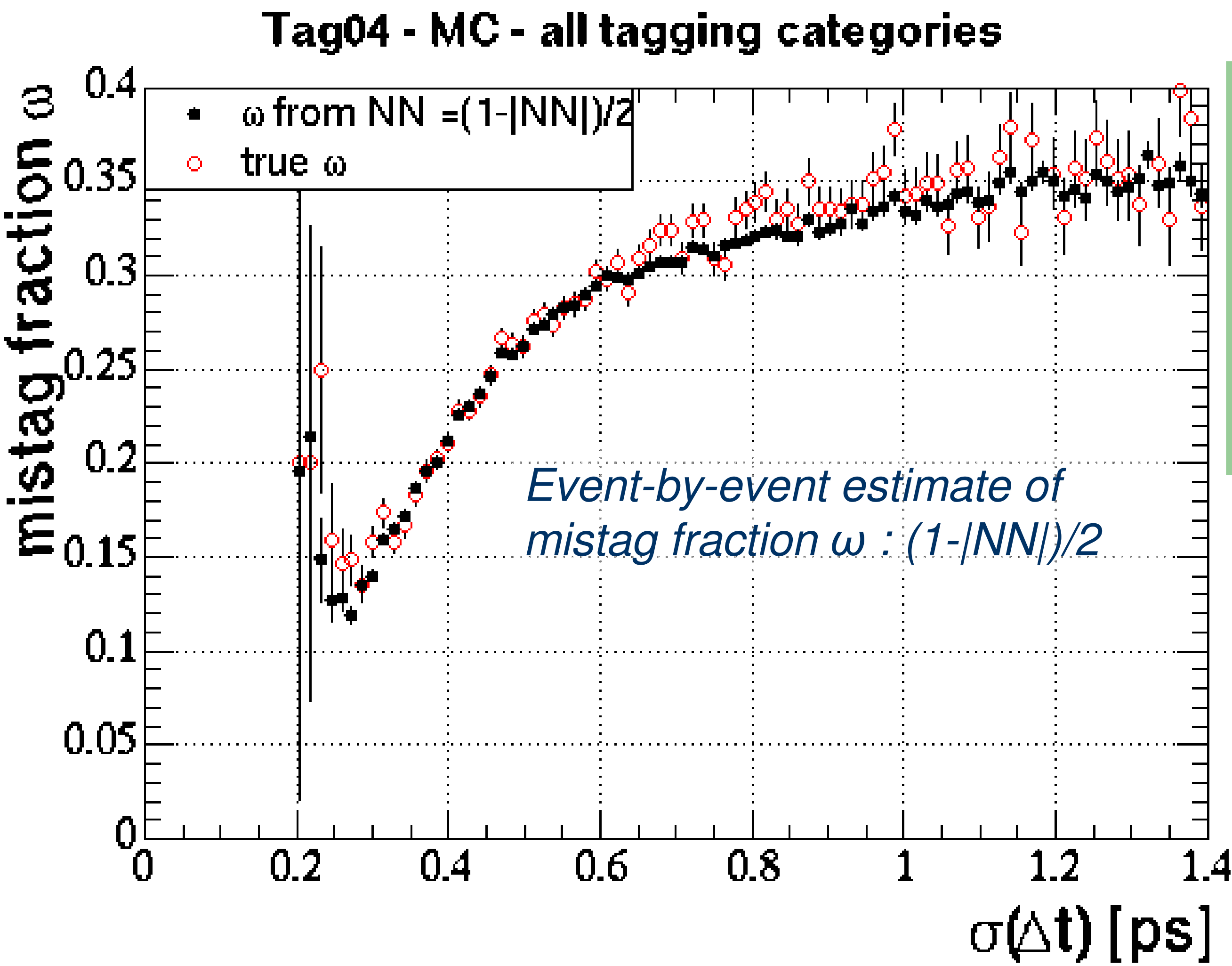
$$Q = \sum_{i=1}^{ncats} \varepsilon_i D_i^2 = \sum_{i=1}^{ncats} \varepsilon_i \overline{NN}_i^2$$

$$\sigma(\sin(2\beta)) \propto \sqrt{Q}$$

~ 10% improvement in Q
~ 3% improvement in σ(sin(2β))



ω – σ(Δt) correlation



Correlation between mistag fraction ω and the resolution in Δt is due the fact that low momentum particles give both imprecise vertices and uncertain tags.

correlation effectively neutralized with 6 categories (4 was too little)

Fitted parametrization

	MC - Parametrized raw
$\sin(2\beta)$	0.7099 ± 0.0048
ω^{signal}_{offset} Lepton	-0.0016 ± 0.0012
ω^{signal}_{offset} Kaon1	-0.0031 ± 0.0014
ω^{signal}_{offset} Kaon2	0.0030 ± 0.0015
ω^{signal}_{offset} KaonPion	0.0032 ± 0.0020
ω^{signal}_{offset} Pions	-0.0005 ± 0.0021
ω^{signal}_{offset} Other	-0.0080 ± 0.0026
ω^{signal}_{slope} Lepton	1.0065 ± 0.0436
ω^{signal}_{slope} Kaon1	1.0164 ± 0.0233
ω^{signal}_{slope} Kaon2	1.0229 ± 0.0104
ω^{signal}_{slope} KaonPion	1.0046 ± 0.0079
ω^{signal}_{slope} Pions	0.9856 ± 0.0058
ω^{signal}_{slope} Other	0.9906 ± 0.0061
$\Delta\omega^{signal}$ Lepton	0.0011 ± 0.0020
$\Delta\omega^{signal}$ Kaon1	-0.0015 ± 0.0021
$\Delta\omega^{signal}$ Kaon2	-0.0087 ± 0.0021
$\Delta\omega^{signal}$ KaonPion	-0.0267 ± 0.0025
$\Delta\omega^{signal}$ Pions	0.0607 ± 0.0026
$\Delta\omega^{signal}$ Other	0.0511 ± 0.0032

Slopes and intercepts from full simultaneous fit on MC (800k BReco + 600k B0gold):

Offset ~0
Slope ~1

$$\omega = \omega_{\text{offset}} + \omega_{\text{slope}} \left(\frac{1-|NN|}{2}\right) \pm \Delta\omega$$

No splitting
(GG resolution model)

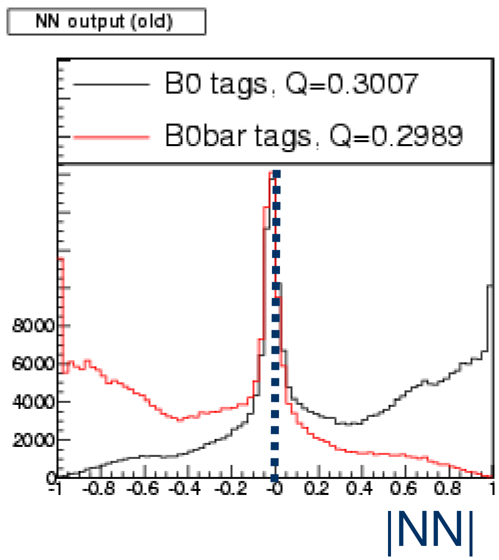
	Parametrized - Tag/Notag
$\sin(2\beta)$	0.7038 ± 0.0042
$\Delta\omega^{signal}$ Tagged	0.0090 ± 0.0008
ω^{signal}_{offset} Tagged	-0.0003 ± 0.0009
ω^{signal}_{slope} Tagged	0.9956 ± 0.0044

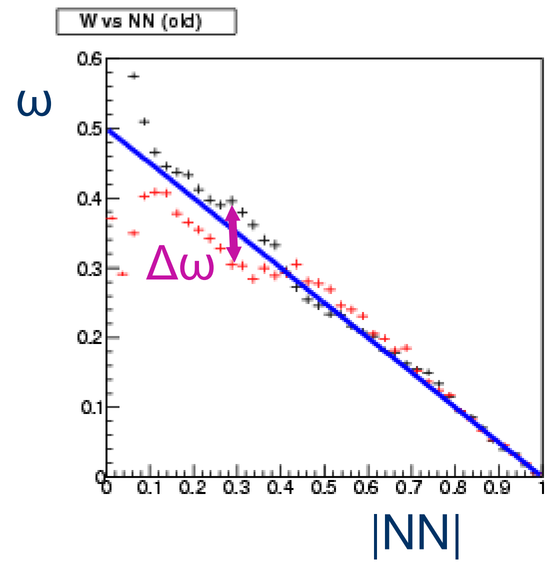
Improvements in training

Problem: NN output is asymmetric between B^0 and $\overline{B}^0$:

• accommodated in CP fits with floating $\Delta\omega$

• prevented use of NN output as *per-event probability* in Summer04

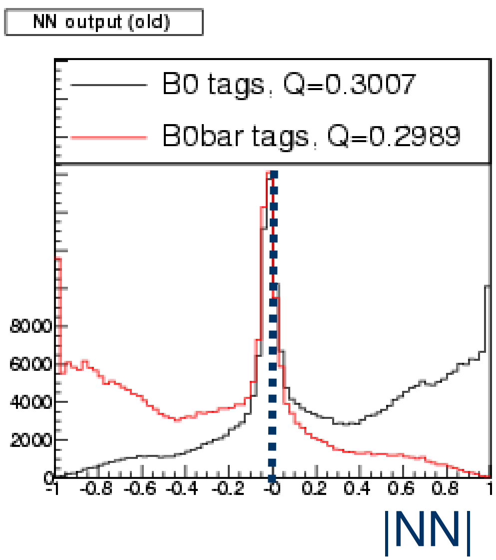




	Cut	ω	Δω
Lepton	|NN|>0.8	0.032(8)	-0.004(8)
Kaon I	|NN|>0.8	0.046(7)	-0.013(9)
Kaon II	0.6<|NN|<0.8	0.156(6)	-0.013(8)
KaonPion	0.4<|NN|<0.6	0.237(7)	-0.003(9)
Pions	0.2<|NN|<0.4	0.330(7)	**0.049(9)**
Other	0.1<|NN|<0.2	0.441(8)	**0.022(11)**

NN output as probability

The NN output is a (tag flavor) probability if (see Bishop):
• input data can be approximated with sum of Gaussians
• sufficient number of hidden nodes



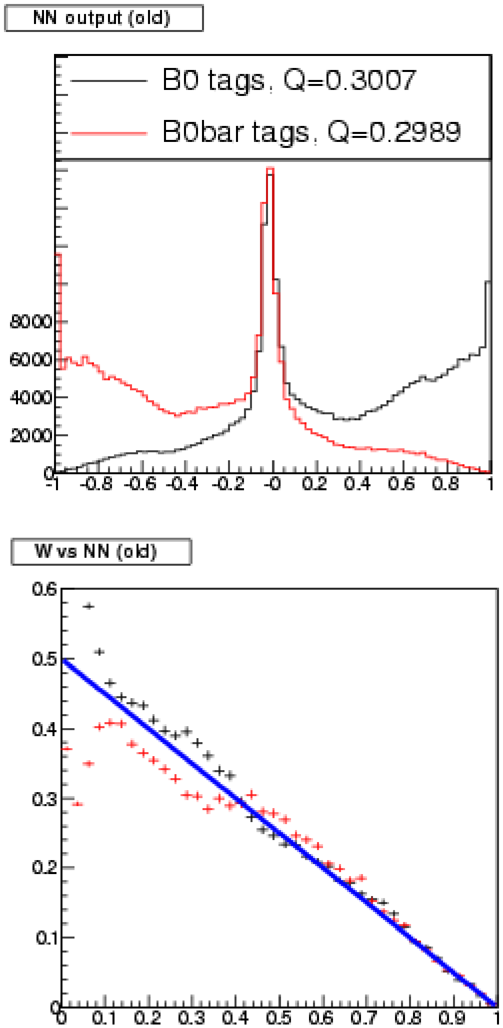
In the past: number of B0 tags and B0bar tags not the same in the training sample:

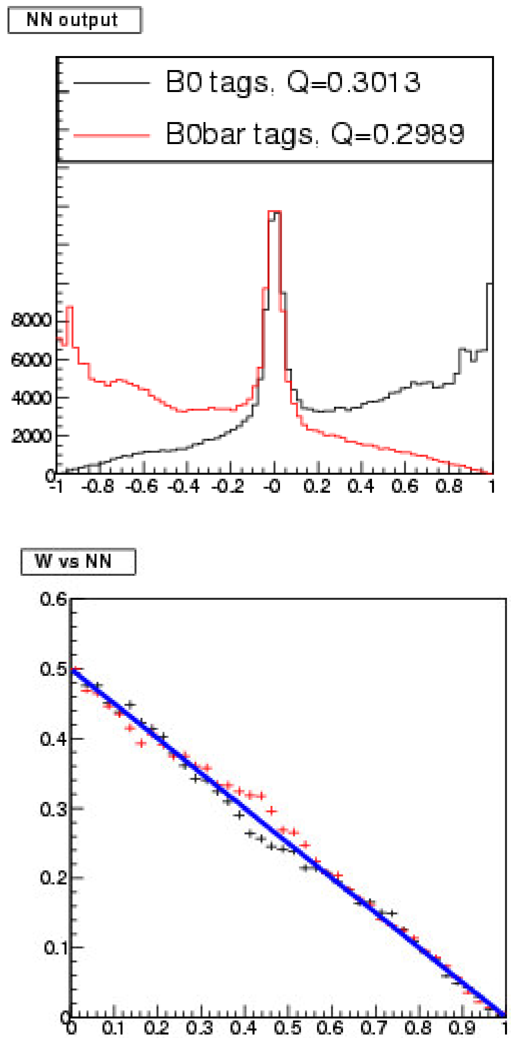
- posterior probability (NN output) for events with hardly any tagging information = prior probability = N(B0)/(Ntot) in training
- leads to nonzero $\Delta\omega$ for events with small |NN|

New strategy:
• retrain all sub-taggers with flavor as training target value
• enforce equal nr of events in training
• duplicate training patterns with flavor-mirrored copy

Results of new training

Before





After

Summary & Plans

- NIM paper in the making
- Run 5, R18 validation
  - Help welcome from 1 grad student (service work!)
- Will provide tagging parameters on standard data sets
- Still exploring ways to improve Q
  - Ilya is investigating extra inputs and alternative classifiers
  - Many studies done in the past, Tag04 close to optimal
  - Try all-in-one training (one NN with all sub-taggers)
- Will provide improved version of Tag04 (Tag06?) with more symmetrical NN output
  - Useful for parametrized mistag rates in time-dependent analysis
  - Hopefully will be able to increase Q as well