EF01: Higgs Couplings and properties

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2020-06-28

EF01 focus more on FCC-hh, such as HH
No much discussion on e+e- experiment

June 2020

24 Jun EF01 meeting

May 2020

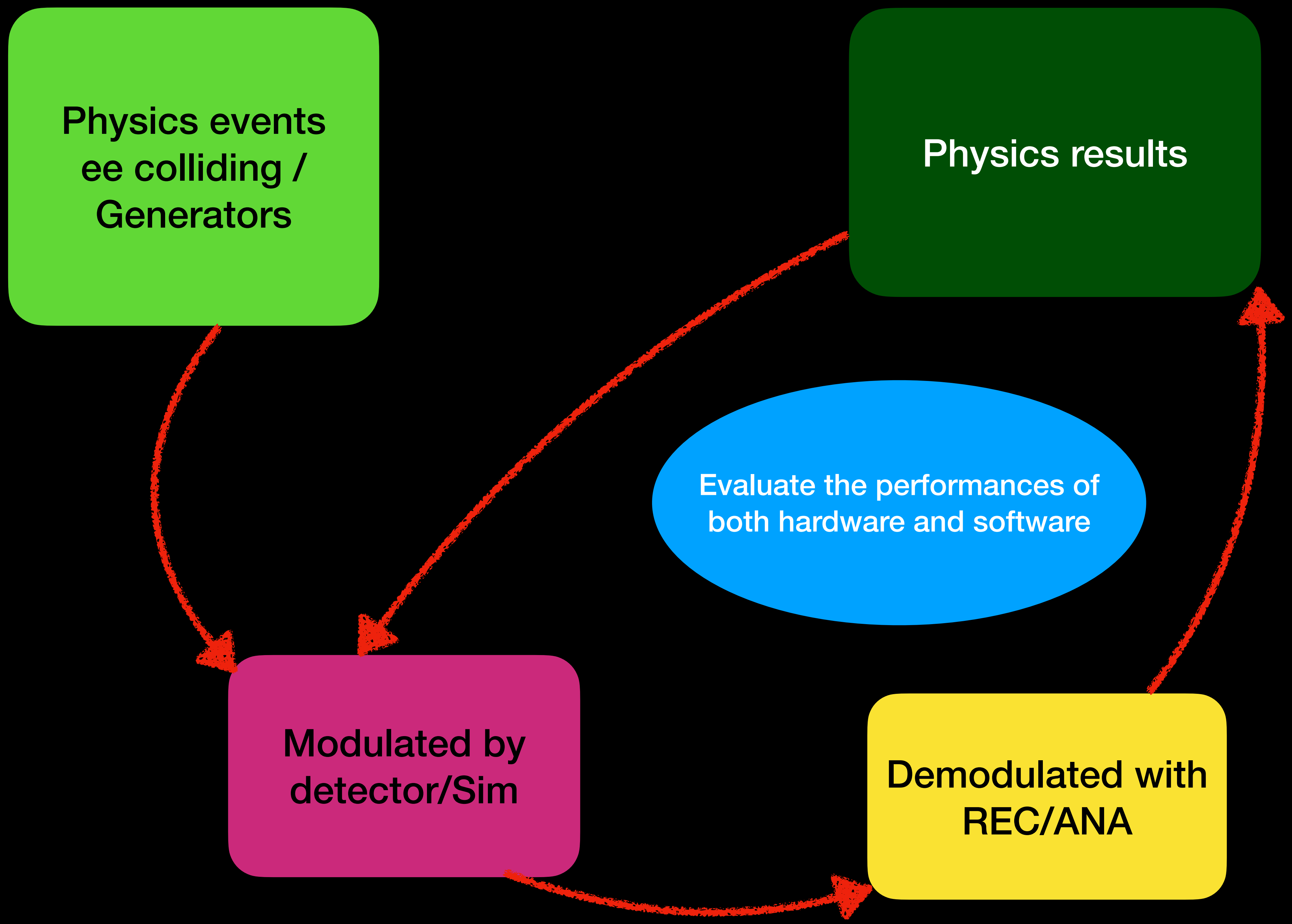
27 May Joint EF01 & EF02 discussion

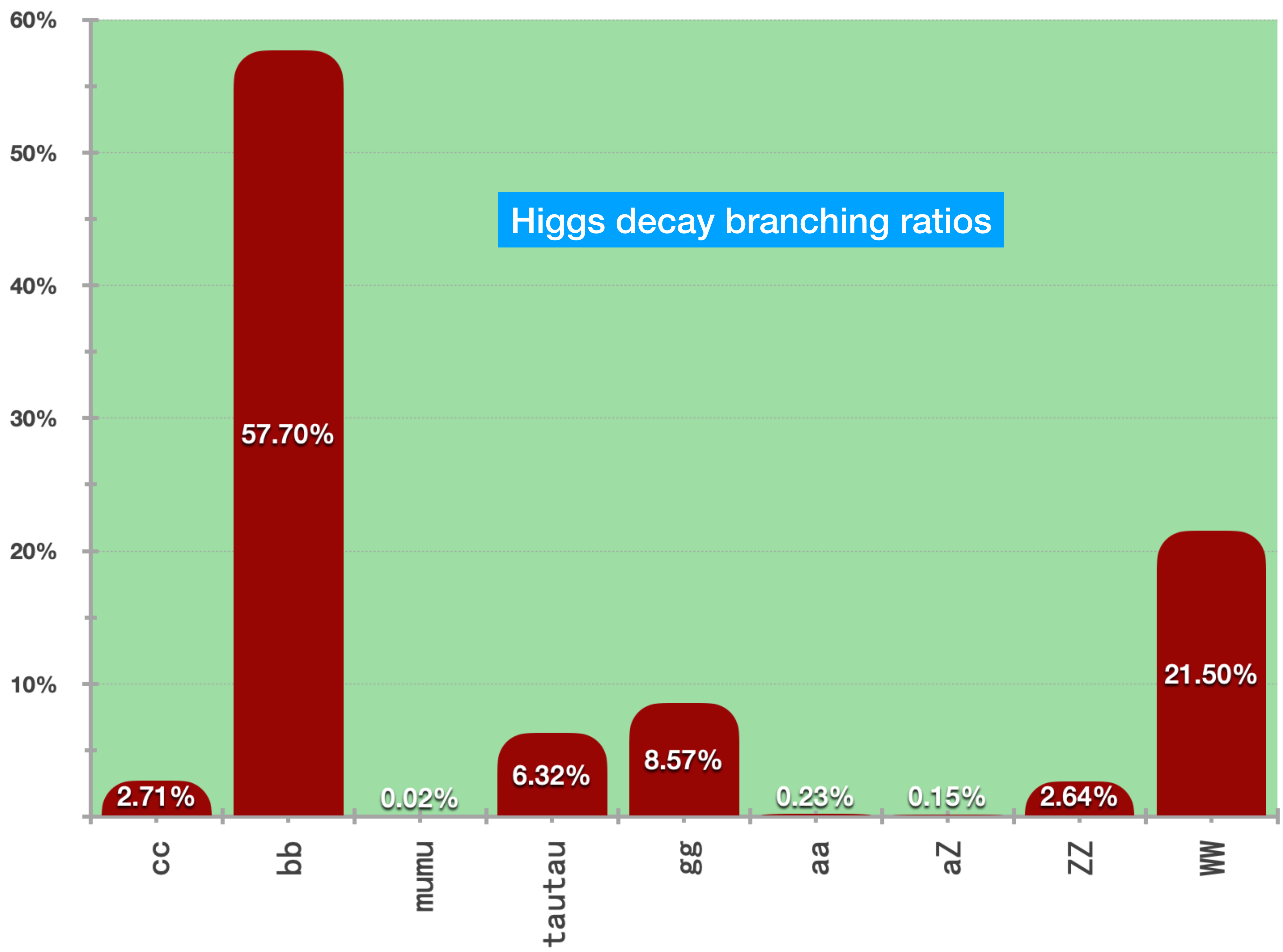
13 May EF01 kick-off meeting

Higgs study: primary goal of the CEPC

- 9 Br's $c\bar{c}, b\bar{b}, \mu\mu, \tau\tau, gg, \gamma\gamma, \gamma Z, ZZ, WW$ $(d\bar{d}, u\bar{u}, s\bar{s}, e^{+}e^{-}, t\bar{t})$
- σ_{ZH} , $\sigma_{\nu\bar{\nu}H}$, mass, differential distributions,
  - Combination: couplings, width, CP, …
- Exotic decays of Higgs
- Precision study, also interplay with EF02
  - Precision measurements lead discovery

Higgs study: guiding star of DET/SW/ANA optimization





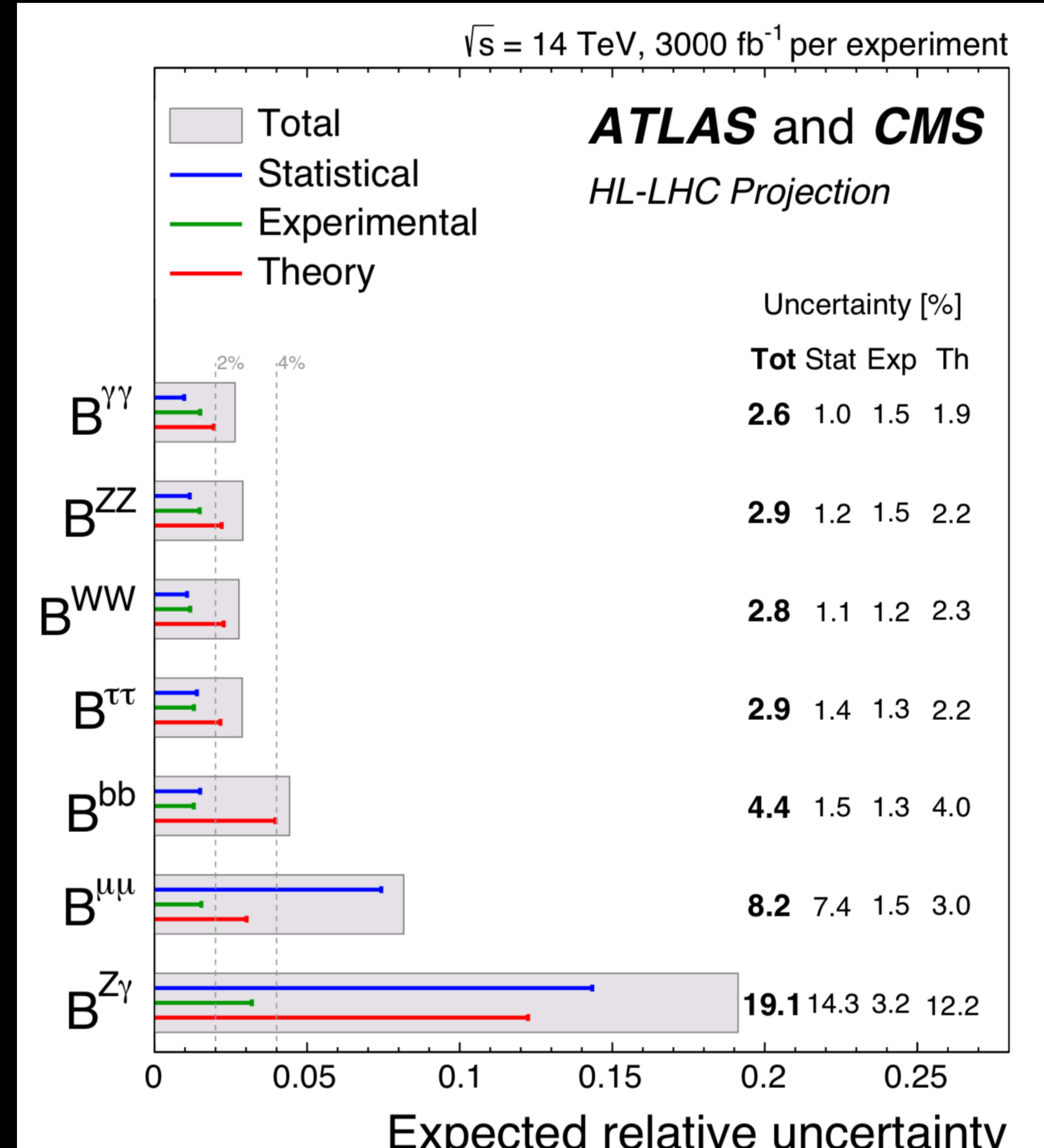
Higgs decay branching ratios
60%
50%
40%
30%
20%
10%
2.71%
57.70%
0.02%
6.32%
8.57%
0.23%
0.15%
2.64%
21.50%
cc
bb
mumu
tautau
gg
aa
aZ
ZZ
WW

How to get the best precisions
Approach to the stats. limits

Property	Estimated Precision
m_H	5.9 MeV
Γ_H	3.1%
$\sigma(ZH)$	0.5%
$\sigma(\nu\bar{\nu}H)$	3.2%

CDR
CEPC_v4

Decay mode	$\sigma(ZH) \times$ BR	BR
$H \to b\bar{b}$	0.27%	0.56%
$H \to c\bar{c}$	3.3%	3.3%
$H \to gg$	1.3%	1.4%
$H \to WW^*$	1.0%	1.1%
$H \to ZZ^*$	5.1%	5.1%
$H \to \gamma\gamma$	6.8%	6.9%
$H \to Z\gamma$	15%	15%
$H \to \tau^+\tau^-$	0.8%	1.0%
$H \to \mu^+\mu^-$	17%	17%
$H \to$ inv	–	$< 0.30\%$



More suggestions ?

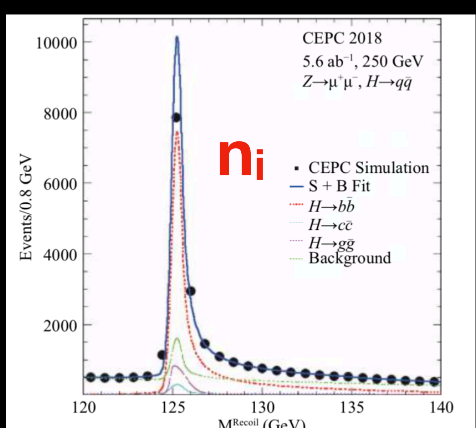
- We should focus on e+e- colliding
- More new ideas, methods, new topics to extract more information from 1M Higgs events
  - Machine learning
  - Differential analysis
  - Exotics decay
  - … …
  - An example: simultaneous analysis (slowly moving forward)

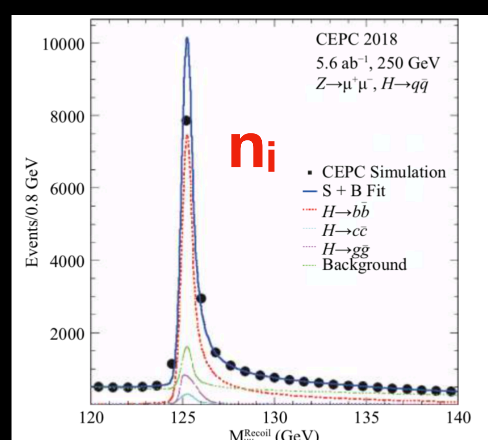
Simultaneous analysis

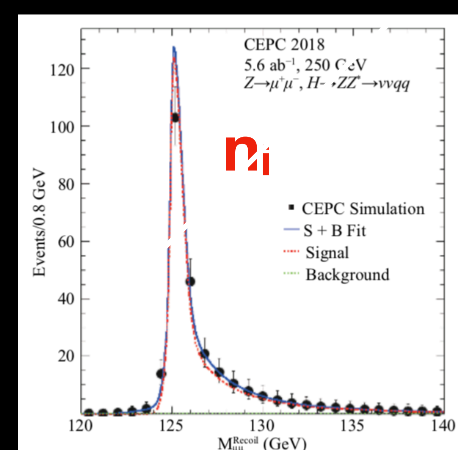
- Tagging method to get denominator: constraint $\sum N_i = N$
- All Higgs decays selected simultaneously
- Multinomial distribution: smaller stat. uncert.

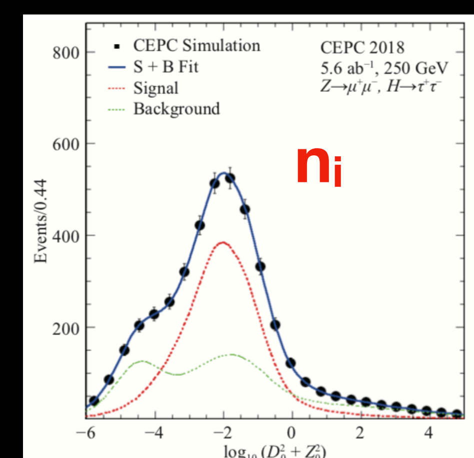
$$\sigma_{n_i} = \sqrt{Np\epsilon_{ii}}$$

$$\sigma_{n_i} = \sqrt{Np(1-p)\epsilon_{ii}}$$

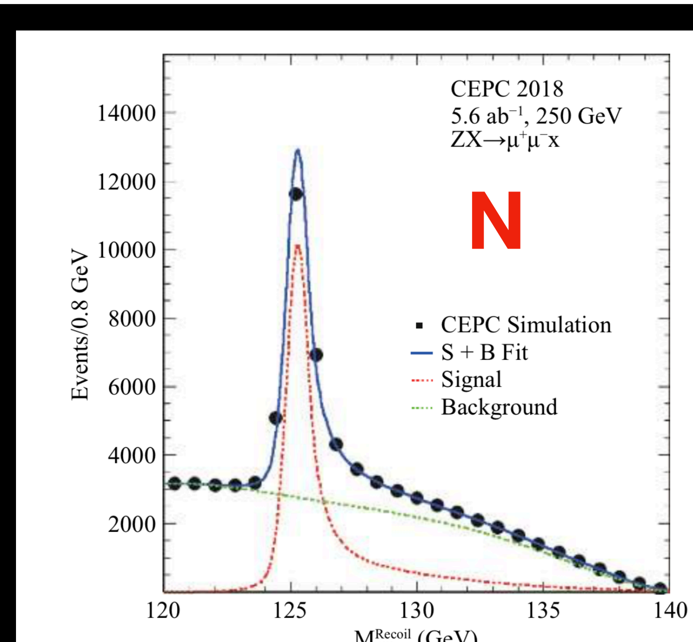






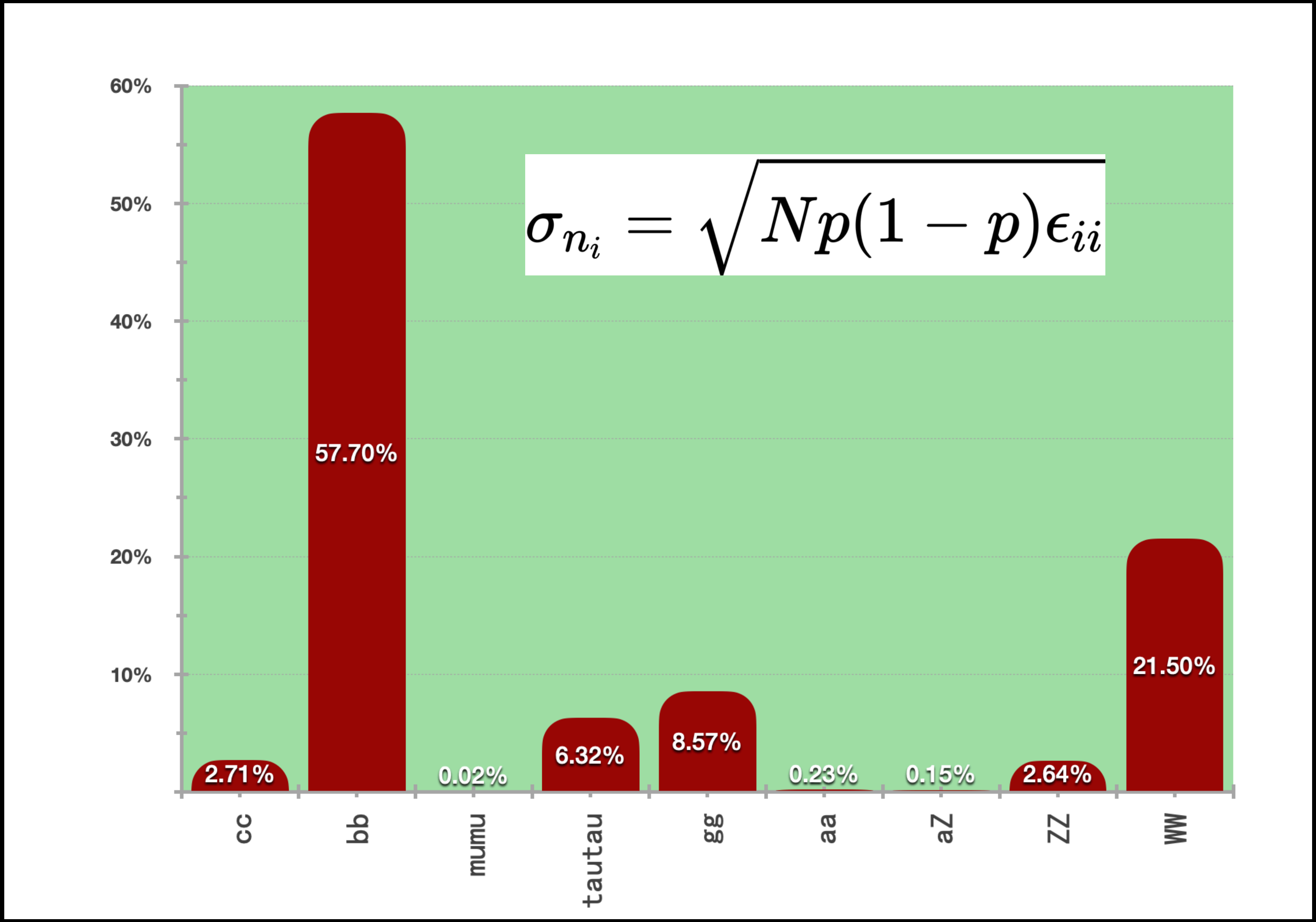


+ … …



$$B_i = \frac{n_i/\epsilon_{ii}}{N}$$

Multinomial dist. in Higgs decays



$$\sigma_{n_i} = \sqrt{Np(1-p)\epsilon_{ii}}$$

Physics performance — characterized by a single parameter which can be parameterized with hardware/software performances

$$P = f(\sigma_p, \sigma_{E_\gamma}, PID, JID, JER, \ldots) = |E|^2 \propto \frac{1}{|\Sigma_B|^2}$$

Single parameter, easy to optimize

$$\Sigma_B = \frac{\vec{\sigma}_B \vec{\sigma}_B^T}{N^4 |E|^2}$$

In the Higgs branching ratio measurements

Solve N_i by minimizing the chi^2 with constraint

$$\chi^2 = \sum_i \frac{(\sum \epsilon_{ij} N_j - n_i)^2}{\sigma_{n_i}^2} + \frac{(\sum_l N_l - N)^2}{\sigma_N^2}$$

Higgs -> cc, bb, mm, tt, gg, aa, aZ, ZZ, WW

1 2 3 4 5 6 7 8 9

$$\begin{pmatrix} n_1 \\ n_2 \\ n_3 \\ n_4 \\ n_5 \\ n_6 \\ n_7 \\ n_8 \\ n_9 \end{pmatrix} = \begin{pmatrix} \epsilon_{11} & \epsilon_{12} & \epsilon_{13} & \epsilon_{14} & \epsilon_{15} & \epsilon_{16} & \epsilon_{17} & \epsilon_{18} & \epsilon_{19} \\ \epsilon_{21} & \epsilon_{22} & \epsilon_{23} & \epsilon_{24} & \epsilon_{25} & \epsilon_{26} & \epsilon_{27} & \epsilon_{28} & \epsilon_{29} \\ \epsilon_{31} & \epsilon_{32} & \epsilon_{23} & \epsilon_{34} & \epsilon_{35} & \epsilon_{36} & \epsilon_{37} & \epsilon_{38} & \epsilon_{39} \\ \epsilon_{41} & \epsilon_{42} & \epsilon_{33} & \epsilon_{44} & \epsilon_{45} & \epsilon_{46} & \epsilon_{47} & \epsilon_{48} & \epsilon_{49} \\ \epsilon_{51} & \epsilon_{52} & \epsilon_{43} & \epsilon_{54} & \epsilon_{55} & \epsilon_{56} & \epsilon_{57} & \epsilon_{58} & \epsilon_{59} \\ \epsilon_{61} & \epsilon_{62} & \epsilon_{53} & \epsilon_{64} & \epsilon_{65} & \epsilon_{66} & \epsilon_{67} & \epsilon_{68} & \epsilon_{69} \\ \epsilon_{71} & \epsilon_{72} & \epsilon_{63} & \epsilon_{74} & \epsilon_{75} & \epsilon_{76} & \epsilon_{77} & \epsilon_{78} & \epsilon_{79} \\ \epsilon_{81} & \epsilon_{82} & \epsilon_{73} & \epsilon_{84} & \epsilon_{85} & \epsilon_{86} & \epsilon_{87} & \epsilon_{88} & \epsilon_{89} \\ \epsilon_{91} & \epsilon_{92} & \epsilon_{83} & \epsilon_{94} & \epsilon_{95} & \epsilon_{96} & \epsilon_{97} & \epsilon_{98} & \epsilon_{99} \end{pmatrix} \begin{pmatrix} N_1 \\ N_2 \\ N_3 \\ N_4 \\ N_5 \\ N_6 \\ N_7 \\ N_8 \\ N_9 \end{pmatrix}$$

Neglect e,u,d, and s decays and add constraint

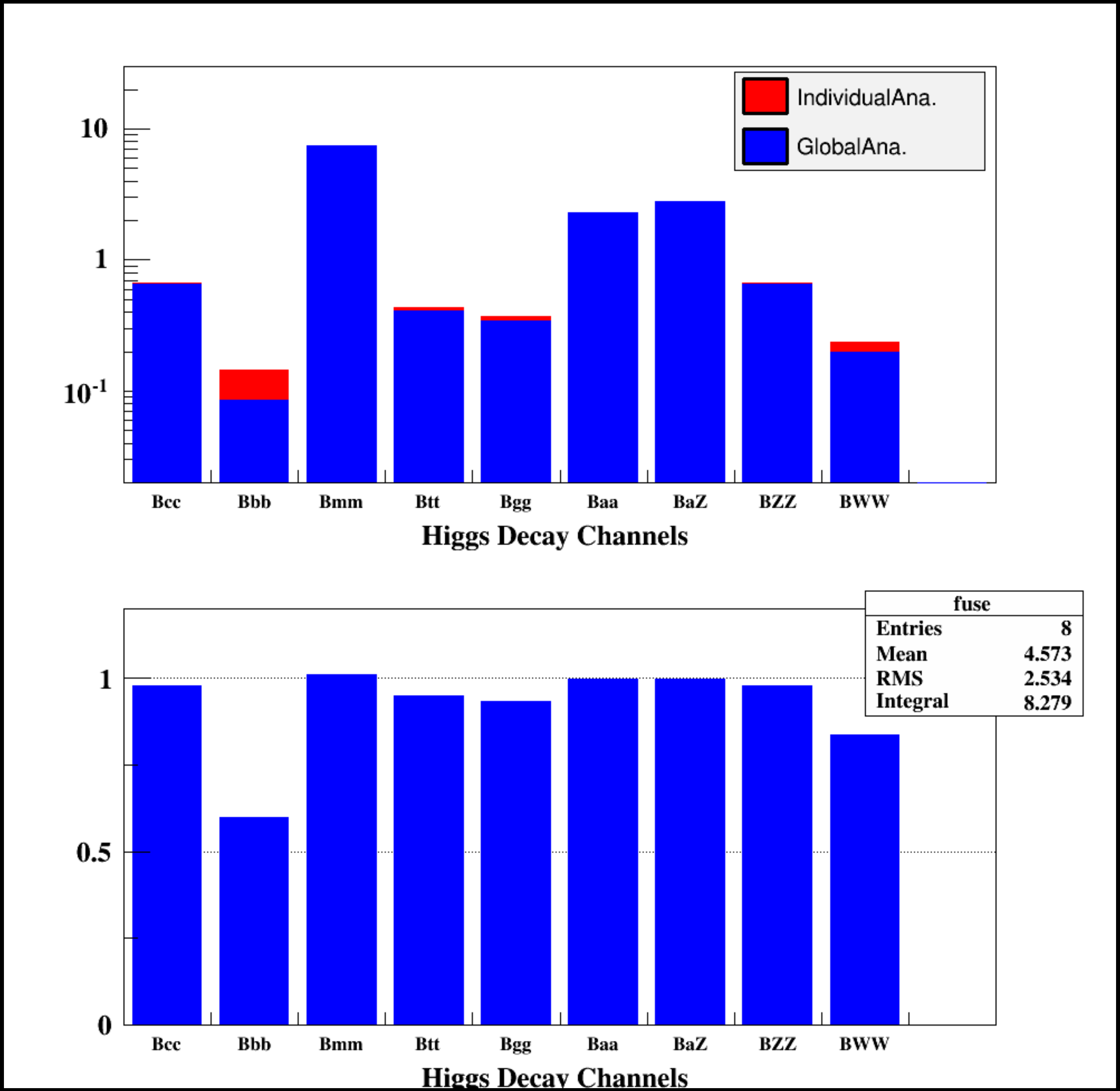
$$\sum_i N_i = N^{tag} \text{ or } \sum_i B_i = 1$$

$$B_i = \frac{N_i}{N}$$

Ideal case:

eeH, qqh as good as uuH

No background, perfect detector, multinomial, and constraint



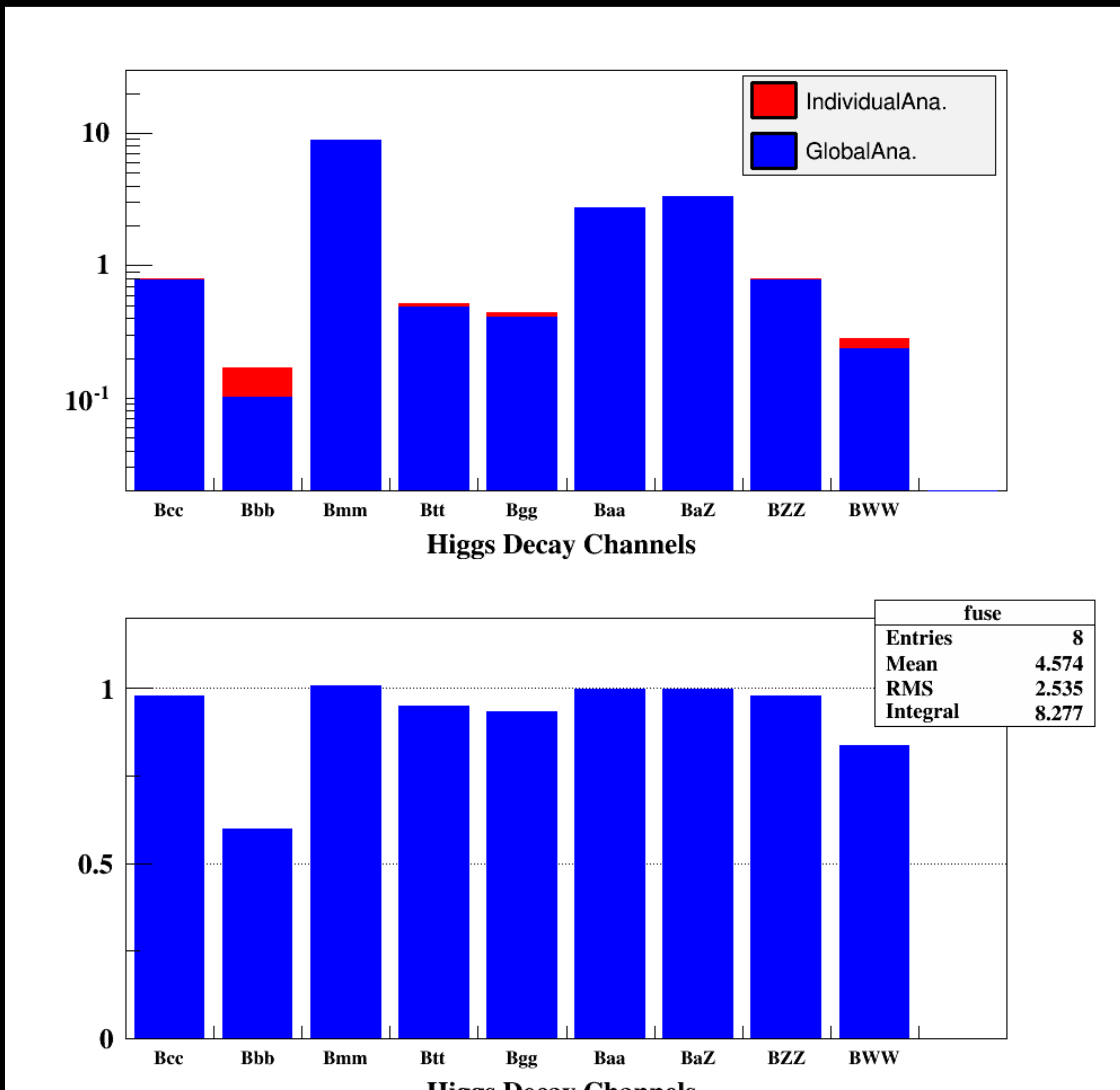
$$\sigma_{n_i} = \sqrt{Np(1-p)\epsilon_{ii}}$$

		MLT		POS
Bcc	2.713%	0.650%	(0.655%	0.664%)
Bbb	57.799%	0.086%	(0.094%	0.144%)
Bmm	0.023%	7.190%	(7.197%	7.198%)
Btt	6.319%	0.413%	(0.421%	0.435%)
Bgg	8.619%	0.347%	(0.356%	0.373%)
Baa	0.227%	2.294%	(2.296%	2.299%)
BaZ	0.150%	2.818%	(2.820%	2.822%)
BZZ	2.647%	0.658%	(0.664%	0.673%)
BWW	21.496%	0.198%	(0.209%	0.236%)

More realistic:

eeH, qqh as good as uuH

100% background, no cross talk, multinomial uncertainties, and constraint



$$\sigma_{n_i} = \sqrt{Np(1-p)\epsilon_{ii}}$$

		MLT		POS
Bcc	2.713%	0.773%	(0.779%	0.790%)
Bbb	57.799%	0.102%	(0.111%	0.171%)
Bmm	0.023%	8.547%	(8.559%	8.560%)
Btt	6.319%	0.492%	(0.501%	0.518%)
Bgg	8.619%	0.413%	(0.424%	0.443%)
Baa	0.227%	2.728%	(2.731%	2.734%)
BaZ	0.150%	3.350%	(3.353%	3.356%)
BZZ	2.647%	0.783%	(0.789%	0.800%)
BWW	21.496%	0.235%	(0.249%	0.281%)