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Improving the precision on Higgs BR

A new approach from an old method

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OUTLINE

Introduction

The old ALEPH method for tau BRs

The proposed new one for Higgs BRs

Introduction

Once on g_{ZH} improved (see the talk of Jonas Kunath)

A good precision on the Higgs BR provides a good precision on Γ_{tot}
But also to all individual decays couplings

How to improve the BR precision in a model independent way !!

Introduction

Table 3. Expected relative precision (%) of the κ parameters in the kappa-0 scenario described in Section 2 for future accelerators. Colliders are considered independently, not in combination with the HL-LHC. No BSM width is allowed in the fit: both BR_{unt} and BR_{inv} are set to 0, and therefore κ_V is not constrained. Cases in which a particular parameter has been fixed to the SM value due to lack of sensitivity are shown with a dash (-). A star ($\star$) indicates the cases in which a parameter has been left free in the fit due to lack of input in the reference documentation. The integrated luminosity and running conditions considered for each collider in this comparison are described in Table 1. FCC-ee/eh/hh corresponds to the combined performance of FCC-ee$_{240}$+FCC-ee$_{365}$, FCC-eh and FCC-hh. In the case of HE-LHC, two theoretical uncertainty scenarios (S2 and S2′) [13] are given for comparison.

kappa-0	HL-LHC	LHeC	HE-LHC		ILC			CLIC			CEPC	FCC-ee		FCC-ee/eh/hh
			S2	S2′	250	500	1000	380	15000	3000		240	365	
κ_W [%]	1.7	0.75	1.4	0.98	1.8	0.29	0.24	0.86	0.16	0.11	1.3	1.3	0.43	0.14
κ_Z [%]	1.5	1.2	1.3	0.9	0.29	0.23	0.22	0.5	0.26	0.23	0.14	0.20	0.17	0.12
κ_g [%]	2.3	3.6	1.9	1.2	2.3	0.97	0.66	2.5	1.3	0.9	1.5	1.7	1.0	0.49
κ_γ [%]	1.9	7.6	1.6	1.2	6.7	3.4	1.9	98$\star$	5.0	2.2	3.7	4.7	3.9	0.29
$\kappa_{Z\gamma}$ [%]	10.	–	5.7	3.8	99$\star$	86$\star$	85$\star$	120$\star$	15	6.9	8.2	81$\star$	75$\star$	0.69
κ_c [%]	–	4.1	–	–	2.5	1.3	0.9	4.3	1.8	1.4	2.2	1.8	1.3	0.95
κ_t [%]	3.3	–	2.8	1.7	–	6.9	1.6	–	–	2.7	–	–	–	1.0
κ_b [%]	3.6	2.1	3.2	2.3	1.8	0.58	0.48	1.9	0.46	0.37	1.2	1.3	0.67	0.43
κ_μ [%]	4.6	–	2.5	1.7	15	9.4	6.2	320$\star$	13	5.8	8.9	10	8.9	0.41
κ_τ [%]	1.9	3.3	1.5	1.1	1.9	0.70	0.57	3.0	1.3	0.88	1.3	1.4	0.73	0.44

Taken from contribution to ESPP
Higgs Boson studies at future particle colliders

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The improvement of precision HL-LHC vs ILC is not so fantastic !!!

I think that ILC can do much better than HL-LHC …
We need to work and remember that the final states from e+e- collisions offers many possibilities

The ALEPH METHOD :

- Build a τ sample with controlled bias
- Make a classification
- Extract all BRs with Binomial Stat. uncert.

1 – Select $e^+ e^- \to \tau^+ \tau^-$
with bias on BRs under control

2 – define the variables to be used for identifying
The categories

3 – fit the τ branching ratio to the data sample

* Phys.Rept.421:191-284,2005

classification

Table 3: Definition of the reconstructed τ decay classes. All τ decay modes implemented in the simulation are specified for each class. The notation τ stands for τ^- and the charge conjugate states are implied, while h stands for any charged hadron (π or K).

Class label	Reconstruction criteria	Generated τ decay
e	$1\ e$	$\tau \to e^- \overline{\nu}_e\ \nu_\tau$
μ	$1\ \mu$	$\tau \to \mu^- \overline{\nu}_\mu\ \nu_\tau$
h	$1\ h$	$\tau \to \pi^-\ \nu_\tau$ $\tau \to K^-\ \nu_\tau$ $\tau \to K^{*-}\ \nu_\tau$ $\tau \to \pi^- K^0 \overline{K}^0\ \nu_\tau$ $\tau \to K^- K^0\ \nu_\tau$
$h\ \pi^0$	$1\ h\ +\ \pi^0$	$\tau \to \rho^-\ \nu_\tau$ $\tau \to \pi^-\pi^0\overline{K}^0\ \nu_\tau$ $\tau \to K^-\pi^0 K^0\ \nu_\tau$ $\tau \to K^{*-}\ \nu_\tau$
$h\ 2\pi^0$	$1\ h\ +\ 2\pi^0$	$\tau \to a_1^-\ \nu_\tau$ $\tau \to K^{*-}\ \nu_\tau$ $\tau \to K^-\ 2\pi^0\ \nu_\tau$ $\tau \to \pi^-\omega\ \nu_\tau$ (2) $\tau \to \pi^- K^0 \overline{K}^0\ \nu_\tau$ $\tau \to K^- K^0\ \nu_\tau$
$h\ 3\pi^0$	$1\ h\ +\ 3\pi^0$	$\tau \to \pi^- 3\pi^0\ \nu_\tau$ $\tau \to \pi^-\pi^0\overline{K}^0\ \nu_\tau$ $\tau \to K^-\pi^0 K^0\ \nu_\tau$ $\tau \to \pi^-\pi^0\eta\ \nu_\tau$ (3)
$h\ 4\pi^0$	$1\ h\ + \geq 4\pi^0$	$\tau \to \pi^- 4\pi^0\ \nu_\tau$ $\tau \to \pi^- K^0\overline{K}^0\ \nu_\tau$ $\tau \to \pi^-\pi^0\eta\ \nu_\tau$ (4)
$3h$	$2 - 4h$	$\tau \to a_1^-\ \nu_\tau$ $\tau \to K^{*-}\ \nu_\tau$ $\tau \to K^-\pi^+\pi^-\ \nu_\tau$ $\tau \to K^- K^+ \pi^-\ \nu_\tau$ $\tau \to \pi^- K^0 \overline{K}^0\ \nu_\tau$ $\tau \to K^- K^0\ \nu_\tau$
$3h\ \pi^0$	$2 - 4h + \pi^0$	$\tau \to 2\pi^-\pi^+\pi^0\ \nu_\tau$ (5) $\tau \to \pi^-\pi^0\overline{K}^0\ \nu_\tau$ $\tau \to K^-\pi^0 K^0\ \nu_\tau$
$3h\ 2\pi^0$	$3h + 2\pi^0$	$\tau \to 2\pi^-\pi^+ 2\pi^0\ \nu_\tau$ (6) $\tau \to \pi^- K^0\overline{K}^0\ \nu_\tau$ $\tau \to \pi^-\pi^0\eta\ \nu_\tau$ (7)
$3h\ 3\pi^0$	$3h + \geq 3\pi^0$	$\tau \to 2\pi^-\pi^+ 3\pi^0\ \nu_\tau$
$5h$	$5h$	$\tau \to 3\pi^- 2\pi^+\ \nu_\tau$ $\tau \to \pi^- K^0\overline{K}^0\ \nu_\tau$
$5h\ \pi^0$	$5h + \pi^0$	$\tau \to 3\pi^- 2\pi^+ \pi^0\ \nu_\tau$

[2] With $\omega \to \pi^0\gamma$
[3] With $\eta \to \gamma\gamma$
[4] With $\eta \to 3\pi^0$
[5] This channel includes $\tau \to \pi\omega\ \nu_\tau$ with $\omega \to \pi^-\pi^+\pi^0$
[6] This channel includes $\tau \to \pi\pi^0\omega\ \nu_\tau$ with $\omega \to \pi^-\pi^+\pi^0$
[7] With $\eta \to \pi^-\pi^+\gamma$

The ALEPH METHOD

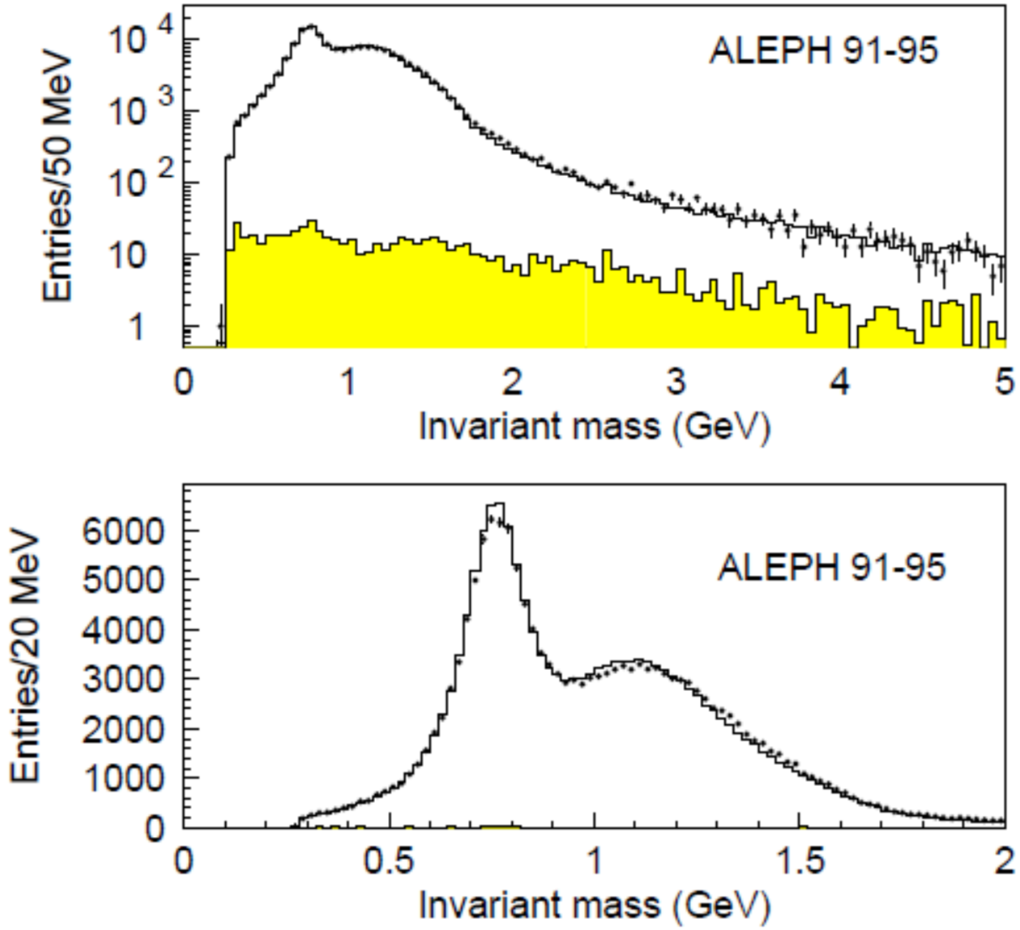


Figure 38: Comparison of mass spectra (assuming all charged particles are pions) in data (points) and simulation (histogram) after fake photon correction for all the hadronic τ decays (except single hadron) in 1991-1995 data sample. The shaded histogram is the contribution of non-τ background. The same plots are displayed in logarithmic (top) and linear (bottom) vertical scales.

The way to control the results

On data, by using distribution
Related to the variables used for
Classification

$\rightarrow$ DATA DRIVEN

Control check based on the TAU branching ratio

Here with the invariant mass of an “hemisphere”

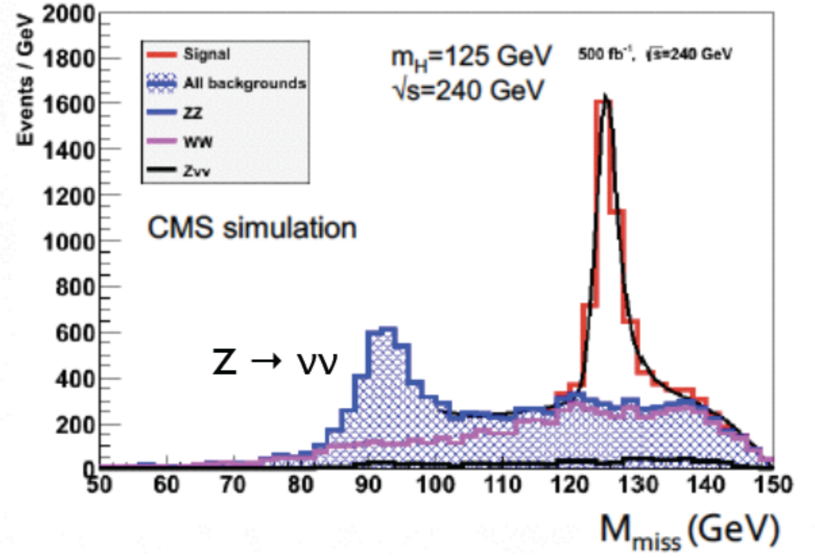
Following the method of ALEPH, I propose

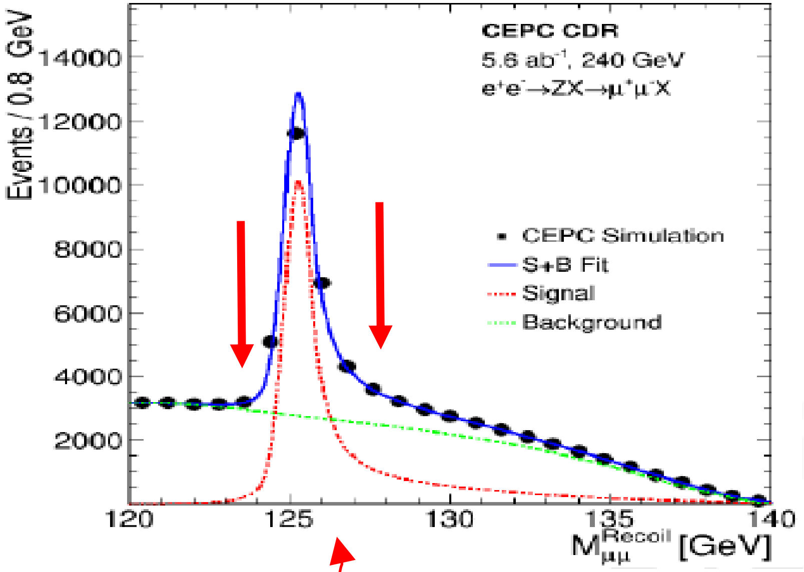
1 – Select a Higgs sample e+ e- $\rightarrow Z\ H$

2 – define the variables to be used

3 – fit the Higgs branching ratio to the data sample

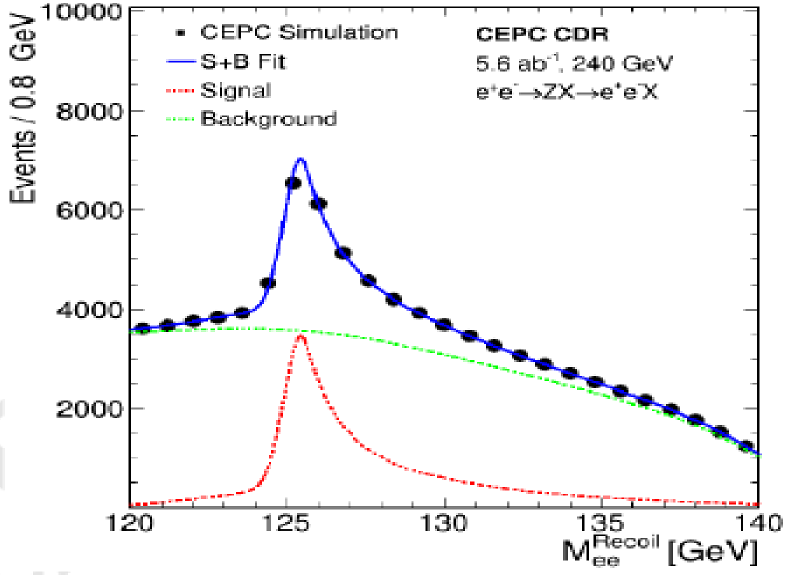
1 – construction of a Higgs sample





Missing mass squared
For di-leptons
…

Define a sample



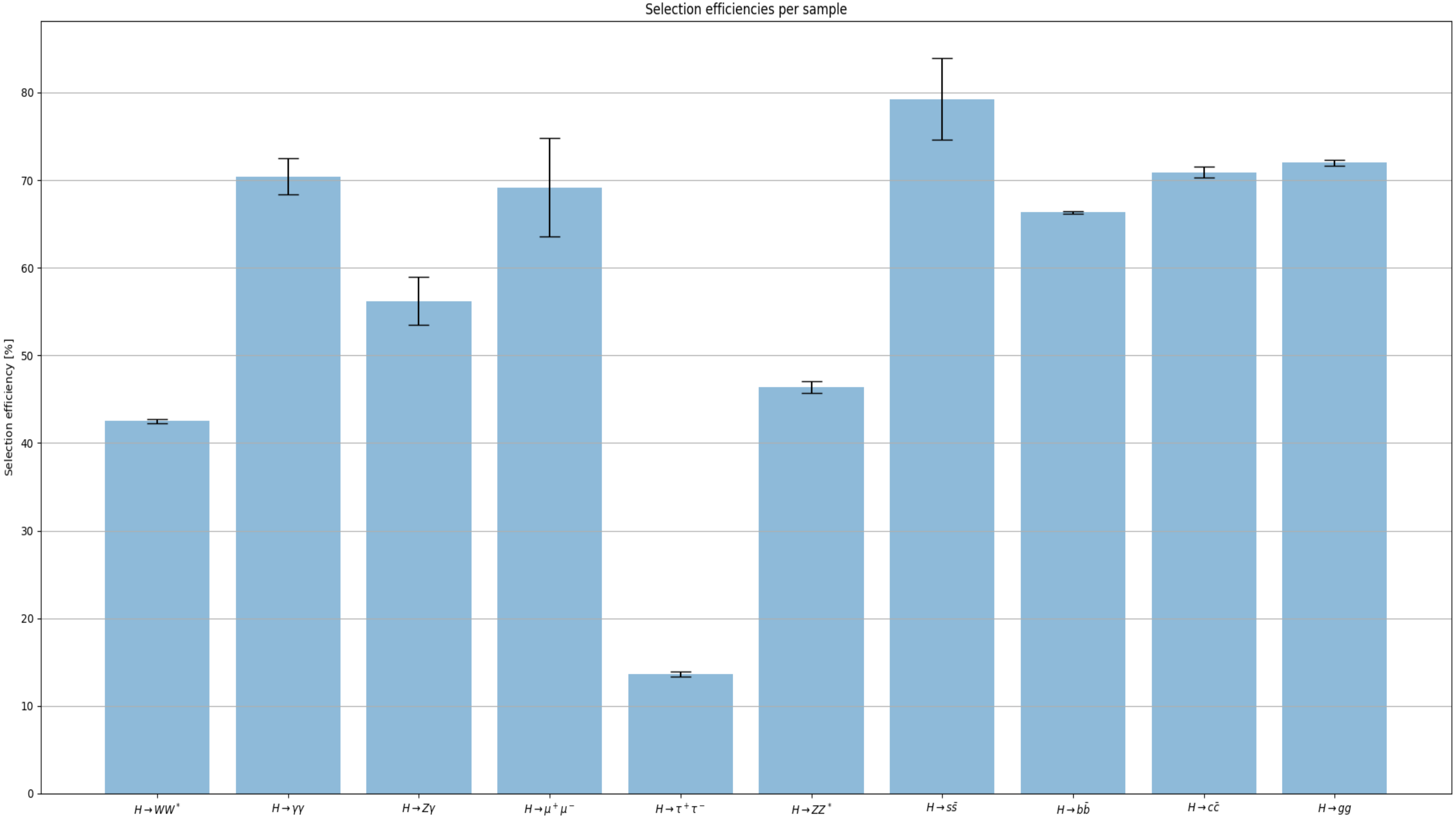
1 – construction of a Higgs sample

Example of sample built for the improved gzh measurement (Jonas Kunath)
It is based on cuts selection at the generator level (no BDT , TMVA or DNN selection)

"Higgs" Sample based on eLpR for 250 fb^{-1}

Z decays	$\mu\mu$	ee	$\tau\tau$	$\nu\nu$
NS	928	1399	1691	11225
NB	471	912	1768	84466

Like in the ALEPH method, the different channels have to be corrected for different selection efficiencies



2 - Exemple of classification

Class label	Recons. Criteria	Higgs decays
b type decays	NB=2 , Nc=Nτ=0,…	bb, ZZ*
uds type	Nb=Nc=Nτ=0	uds,gg, ZZ*,WW*
….	….	….

Probably the best method is to use DNN to do the classification
Which give directly unique response (using all variables)

For b-type decays

Crude Exemple :
- Nb=2
- Njets=2
- Mvis around 125 GeV
- Missing E very low

bb and not ZZ*

DNN will do it much better

3 – fit the Higgs branching ratios to the data sample

1 – Built the vector of variables which optimised the separation of the different Higgs BR
$\overrightarrow{EVTVAR}$ = (Event variables vector) = ($Nh^{\pm}$, Nb, Nc, Ne , Nτ , Nμ , Nγ , Evis, Mvis, Njets(Ycut), …)

2 – Among the Higgs sample, each event has a unique vector

3 – There now a set of vectors representing the whole sample

4 – fit the vector $\overrightarrow{HBR-BKG}$ = (Hbrs , Bkg) which fit the best the set of vectors $\overrightarrow{EVTVAR}$

…

Statistical errors are better than Gaussian errors for large and small BR due to
The fixed number of events in sample which lead to have binomial statistical uncertainties

Conclusion

- We propose to improve the precision on ALL BR of the Higgs decays with a new method
- It is an extension of the method of ALEPH for the measurement of τ decays BRs
- The method proposed is still model independent.
  The binomial errors would improve the precision by a factor which must be important
- Together with the improvement of the coupling g_{zh}, it will provide
  an improved measurement of the total width of the Higgs, leading, with BRs, to ALL couplings

Some collaborations would be of interest for

ILC, CLIC, FCCee and CEPC !!!