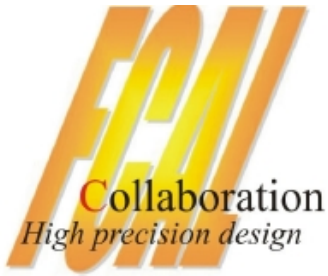


HEP GROUP VINCA

Vinca Belgrade Status report

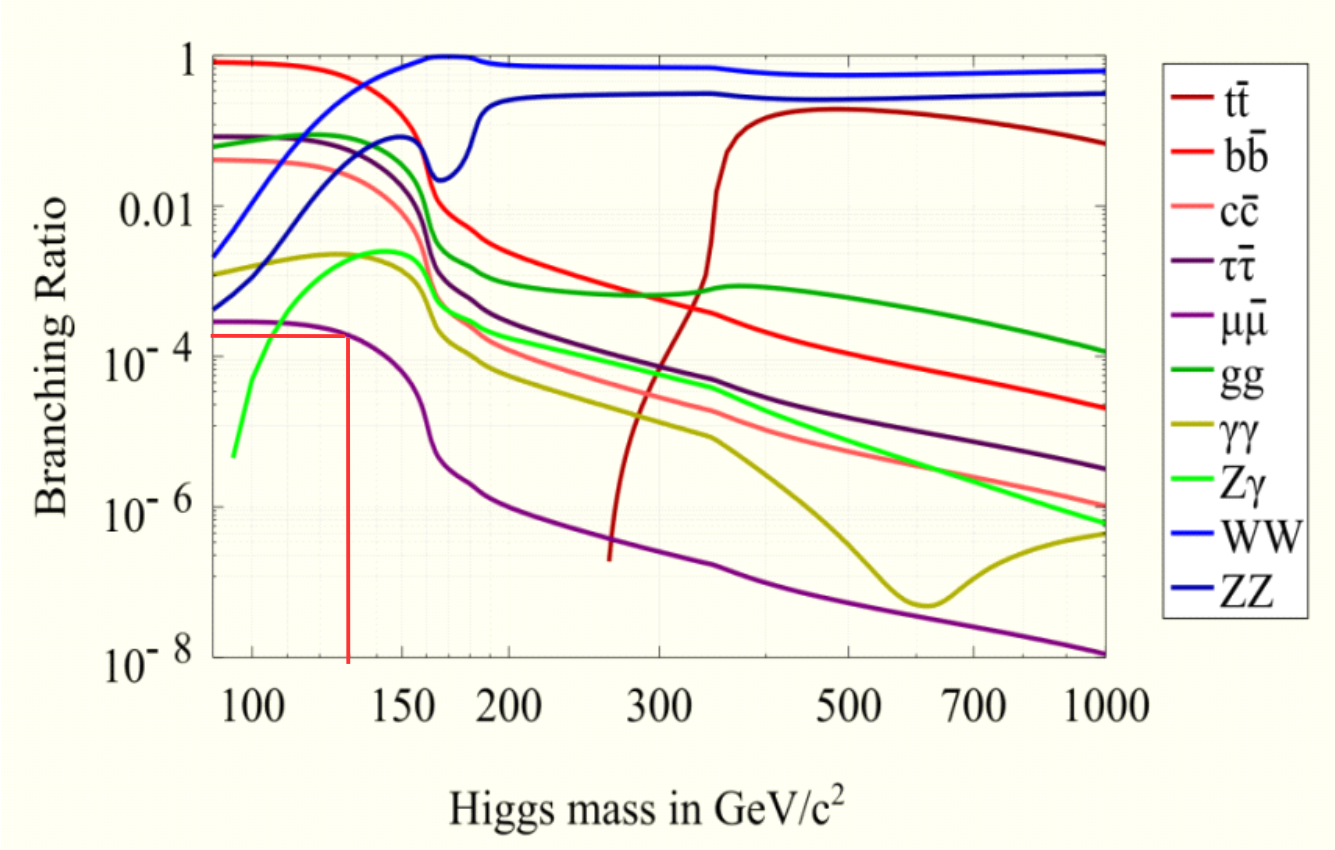
BR measurement of the light Higgs decay into muons at 1.4 TeV CLIC

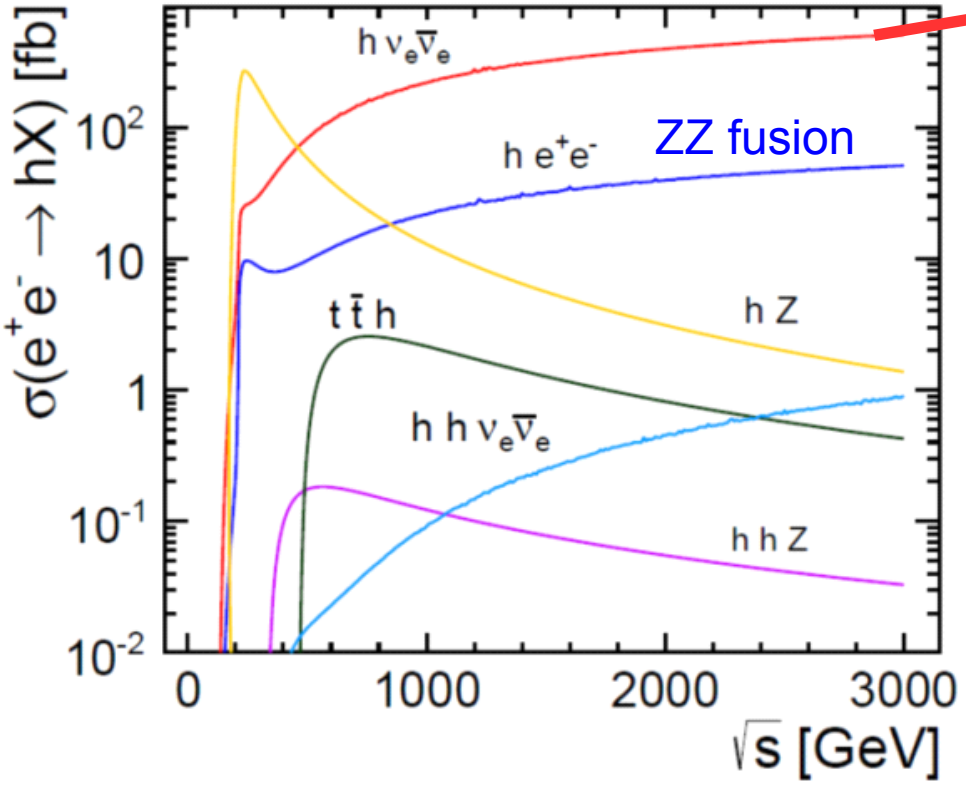
I. Bozovic-Jelisavcic, S. Lukic, M. Pandurovic and G. Milutinovic- Dumbelovic

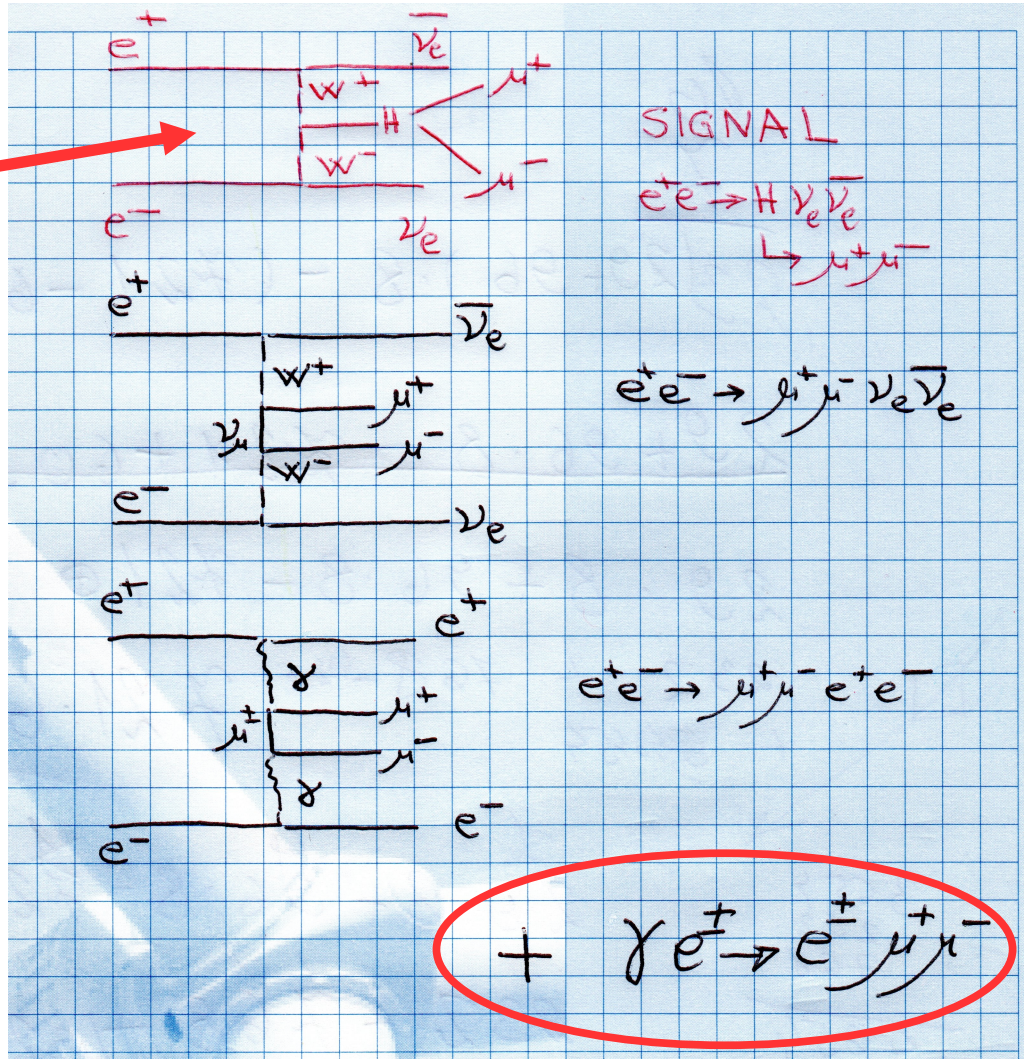
Motivation and status of the measurement

- In SM Higgs BRs depend only on Higgs mass ⇒ potential probe for New Physics
- Challenging measurement due to low signal yield (estimated BR~$3 \cdot 10^{-4}$)
- 3 TeV CLIC cas has already been studied (LCD-NOTE-2011-035)
- It's necessary to complete the Higgs physics case at other CLIC energy stages (Belgrade overtook 1.4 TeV)
- Analysis started in January is already advanced to the level of the result extraction from the Toy MC experiments

Higgs production and decays



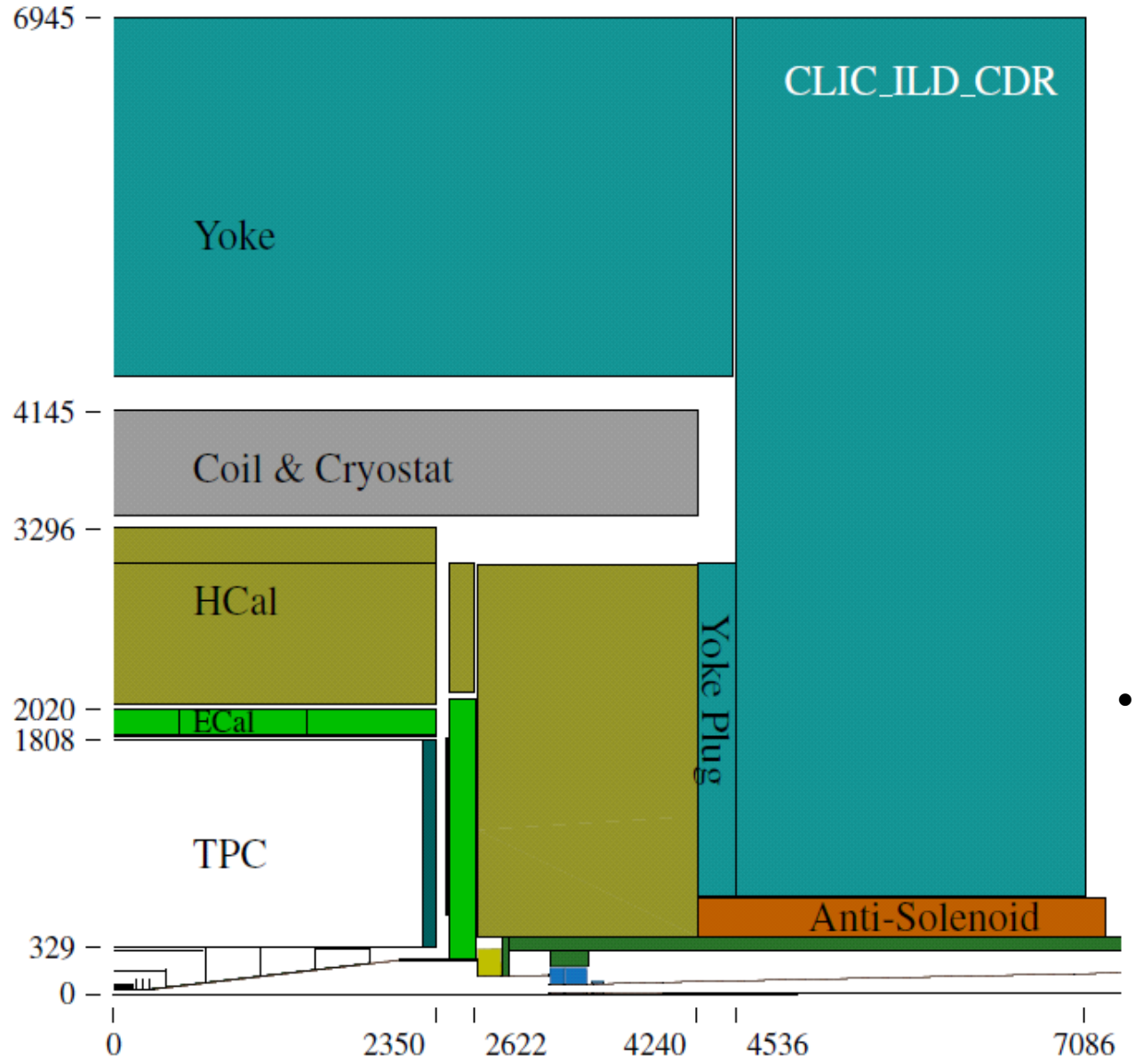

WW fusion
ZZ fusion
$h\nu_e\bar{\nu}_e$
$h e^+e^-$
$t\bar{t}h$
hZ
$hh\nu_e\bar{\nu}_e$
hhZ
$\sigma(e^+e^- \to hX)$ [fb]
10^2
10
1
10^{-1}
10^{-2}
0
1000
2000
3000
$\sqrt{s}$ [GeV]


SIGNAL
$e^+e^- \to H\nu_e\bar{\nu}_e$
$\hookrightarrow \mu^+\mu^-$
$e^+e^- \to \mu^+\mu^-\nu_e\bar{\nu}_e$
$e^+e^- \to \mu^+\mu^- e^+e^-$
$+ \quad \gamma e^- \to e^- \mu^+\mu^-$

Event and detector simulation

(Signal)	[fb]	N
Сигнал $e^+e^- \to h\nu\bar{\nu} \to \mu^+\mu^-\nu\bar{\nu}$	0.068	24000
$e^+e^- \to \mu^+\mu^-\nu\bar{\nu}$	129	236000
$e^+e^- \to \mu^+\mu^- e^+e^-$	431	10^6
$\gamma e^+ \to e^+\mu^+\mu^-$	1280	10^6
$e^-\gamma \to e^-\mu^+\mu^-$	1280	10^6

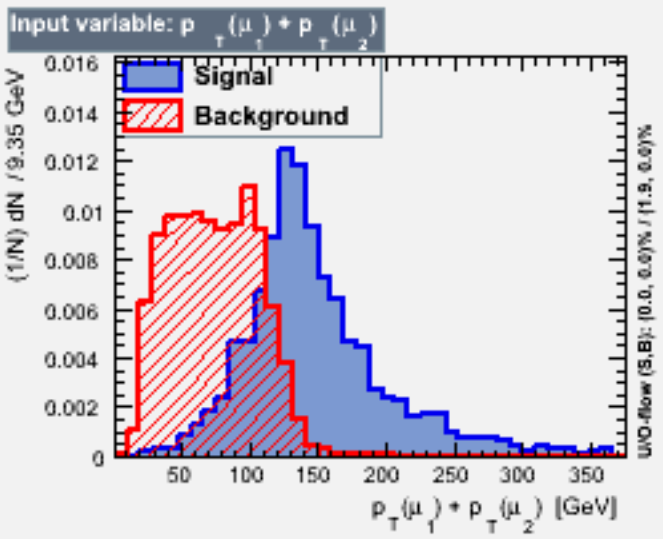
- Everything is normalized to ~1.5 ab^{-1} corresponding to 4 years operation with 50% data taking efficiency ($L=2.1\cdot10^{-34}$ $cm^{-2}s^{-1}$ peak lumi in top 1%of the spectrum)
- Event generation: WHIZARD 1.95 (+ISR), x-angle 20 mrad (Lorentz boost of the final state particles), Higgs decay: PYTHIA 6.4 (+FSR), Lumi spectrum: GuineaPig 1.4.4
- $p_T(\mu)>5$ GeV preselection

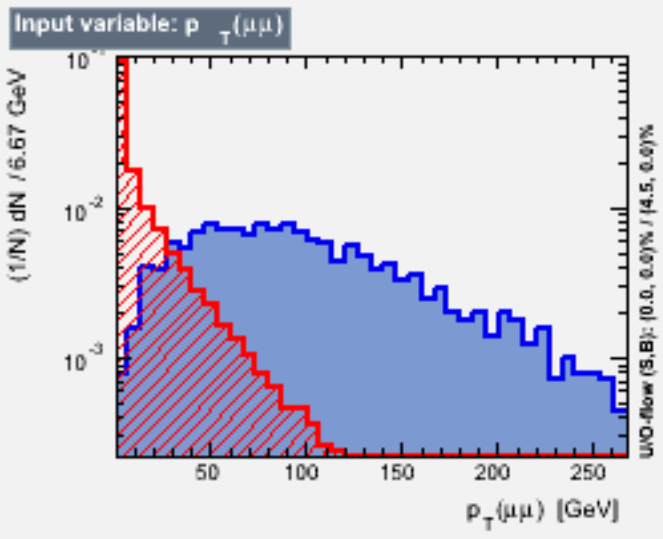


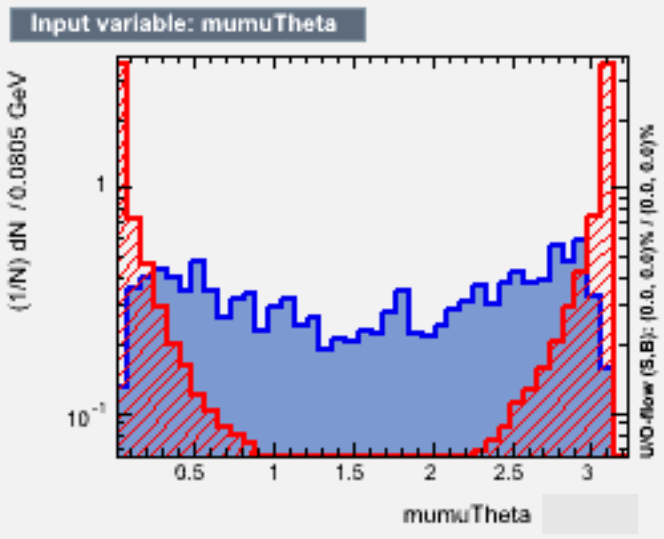
- Challenging p_T muon reconstruction down to the lowest angles ⇒translates into m(μμ) mass width
- Iron yoke instrumented with 9 RPCs for μ identification
- $\Delta p_T/p_T^2$: $1.1 \cdot 10^{-4}$ - $3.5 \cdot 10^{-5}$ GeV^{-1}

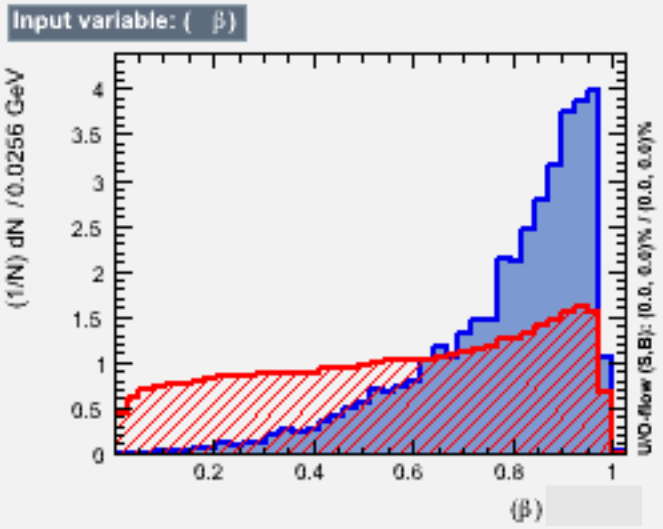
Sensitive observables and multivariate approach in background suppression

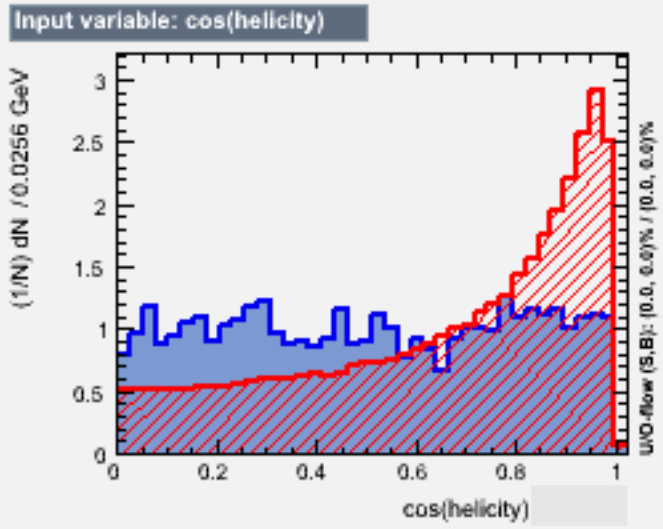
$e^+e^- \rightarrow e^+e^-\mu^+\mu^-$

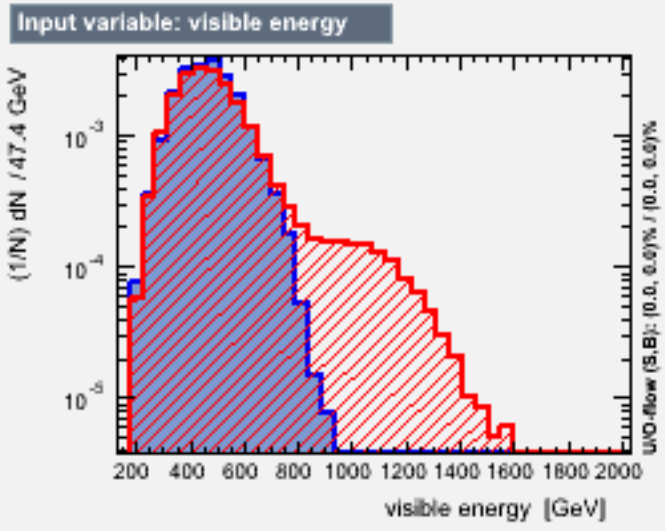


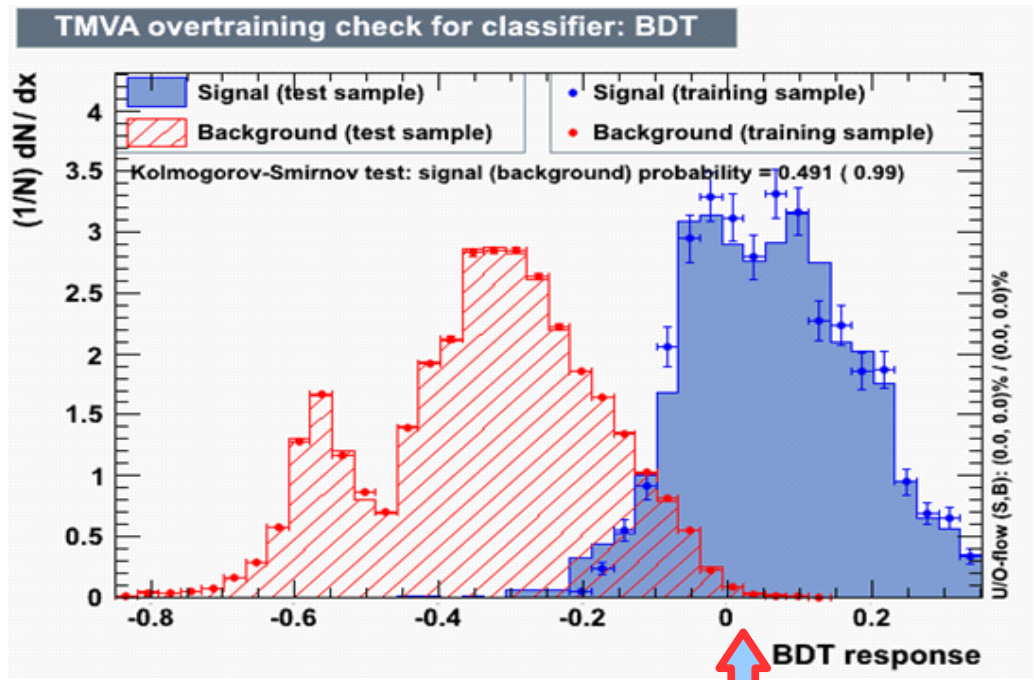


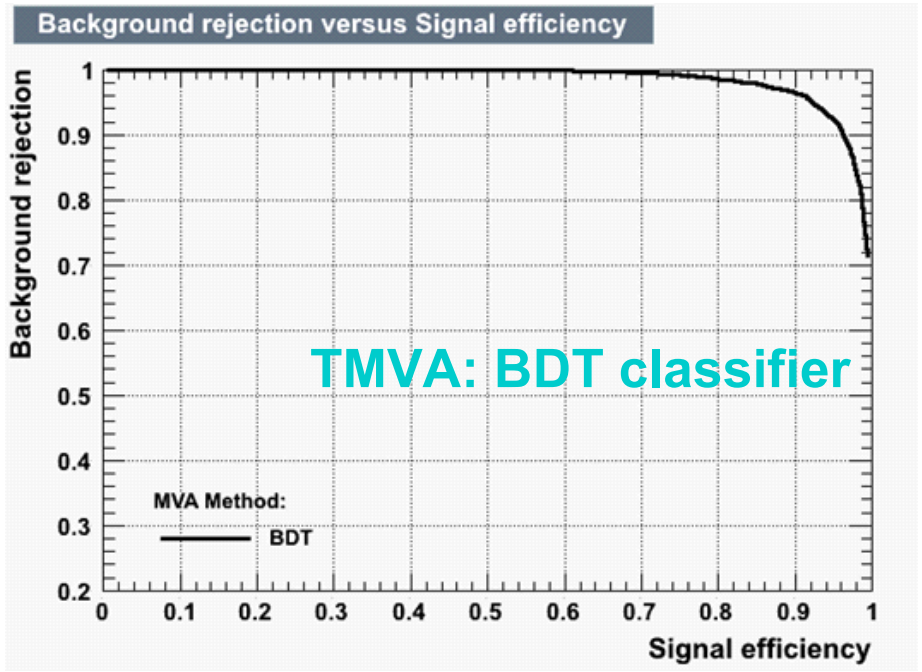




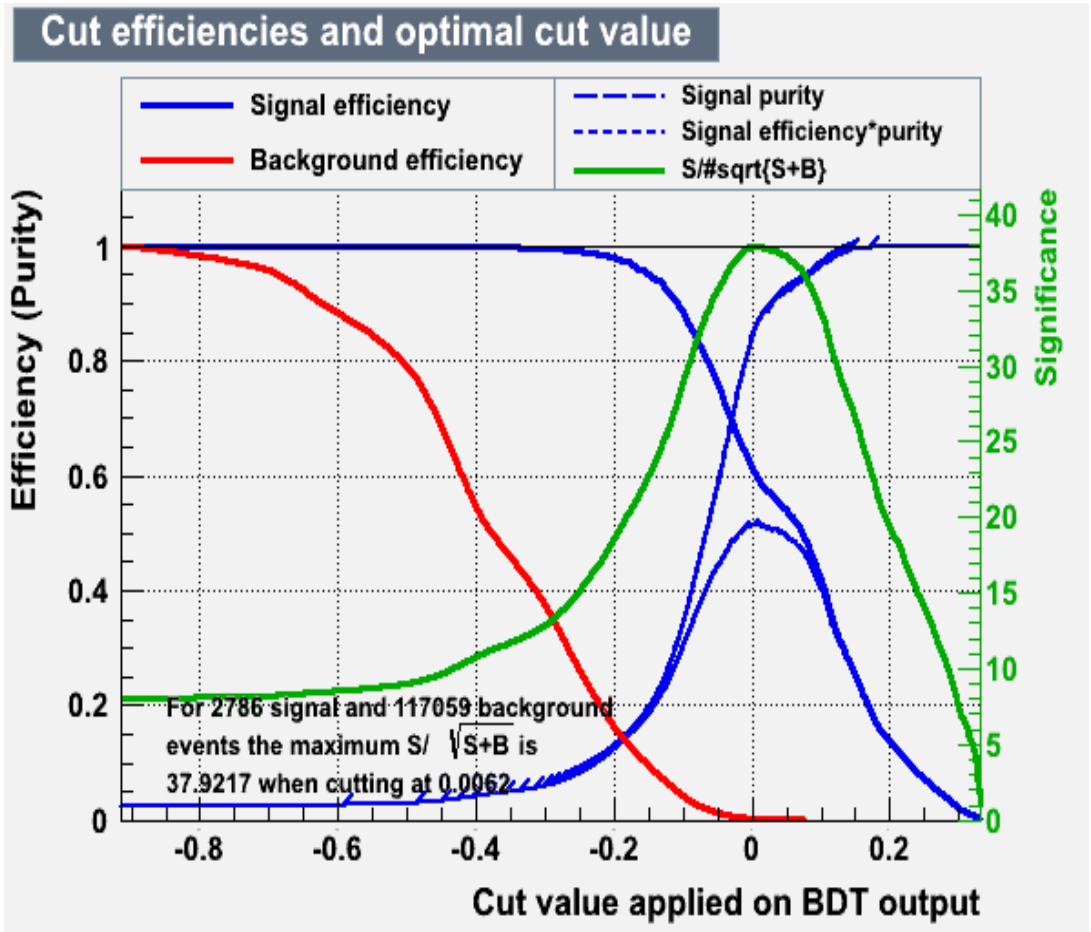


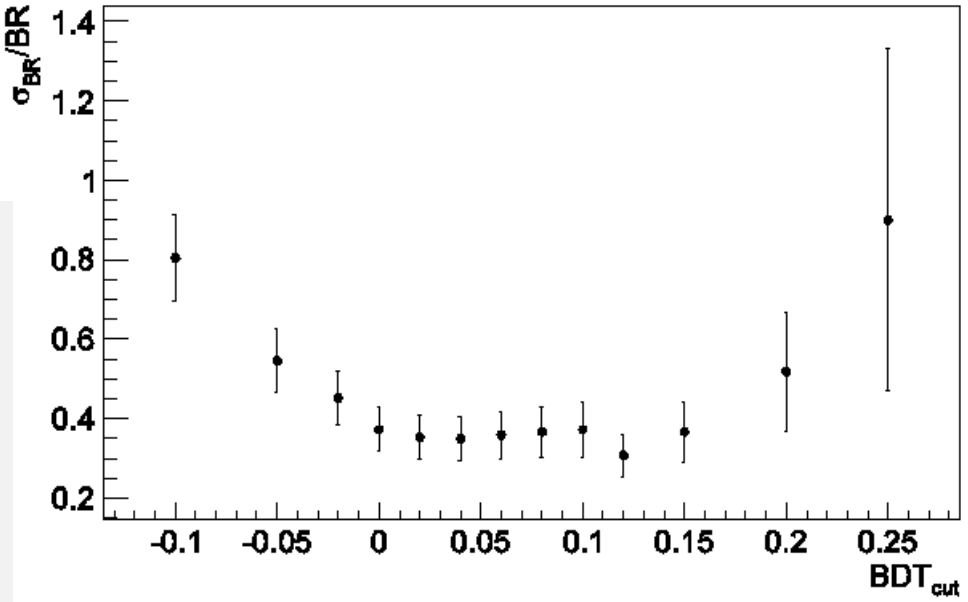



TMVA overtraining check for classifier: BDT
Signal (test sample)
Background (test sample)
Signal (training sample)
Background (training sample)
Kolmogorov-Smirnov test: signal (background) probability = 0.491 (0.99)
(1/N) dN/ dx
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
BDT response


Background rejection versus Signal efficiency
Background rejection
Signal efficiency
TMVA: BDT classifier
MVA Method:
BDT

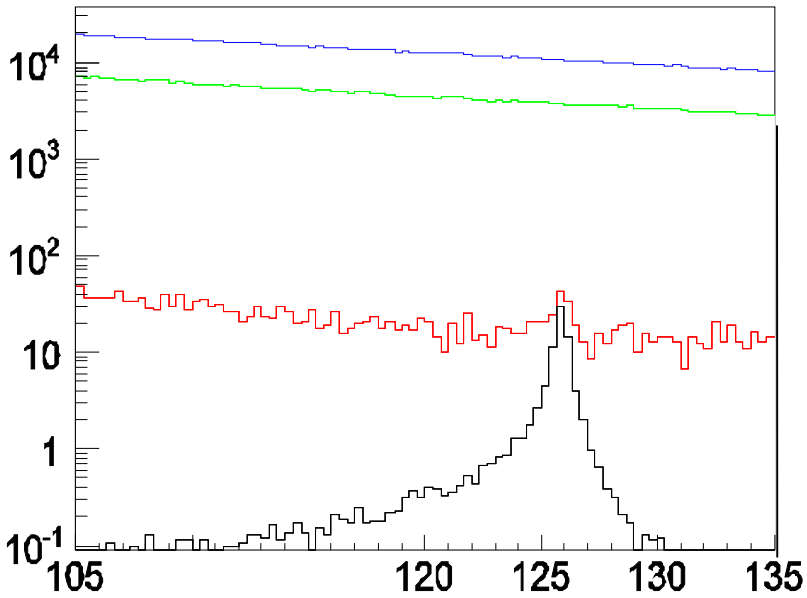
$(BDT)_{out}>0.02$

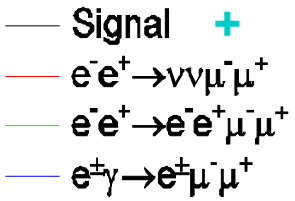


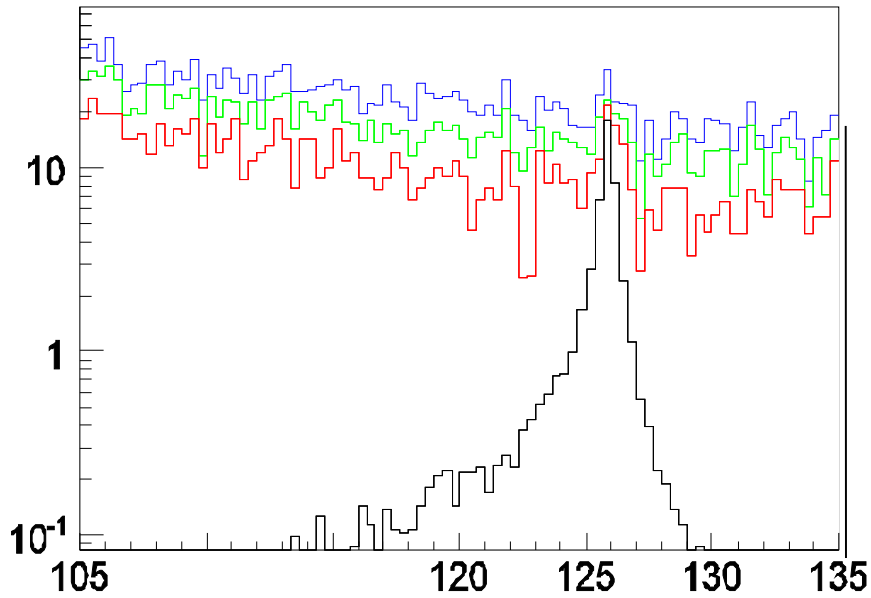


Minimal relative statistical error
⇔ maximization of significance
or purity•efficiency

Residual background after BDT based selection







Reduction of the dominant $e^+e^- \to e^+e^-\mu^+\mu^-$ background by factor 1000

Background with the identical $\mu\mu\nu\nu$ signature can't be further suppressed

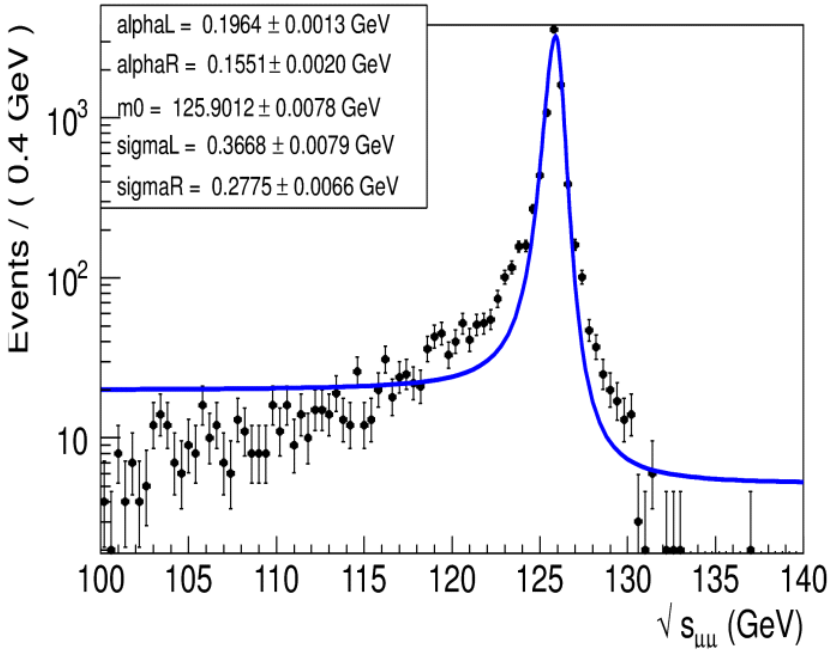
How do we actually measure $BR(H\rightarrow\mu^+\mu^-)$

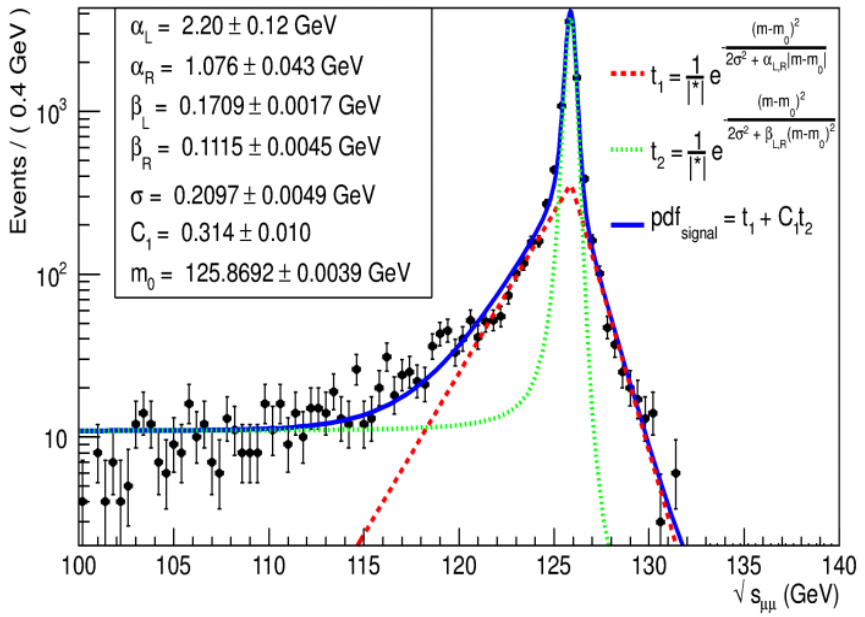
- Expected shape of data (signal + background) has to be fitted (unbinned likelihood fit) by the invariant mass shapes estimated in simulation to derive the number of signal events:

$\sigma_{ww\_fusion} \cdot BR(H\rightarrow\mu^+\mu^-) = N_S / L \cdot \varepsilon_S$

- One needs as large as possible statistics to describe the signal and background (extract PDFs)
- Toy MC: samples drown from the fully simulated signal events + bck PDFs to generate random event samples ($N=\sigma\cdot\varepsilon\cdot L_{1.5}$)
- Sufficient number of Toy MC experiments (i.e. 1000) gives estimates of N_S

Signal PDF*





- **Double-sided Gaussian**
- **(5 parameters)**
- *C.Grefe, PhD Thesis, Uni. Bonn, 2012*
- *LCD Note-2011-035*

- **Composite Gaussian: exp. tail +**
- **flat tail (7 parameters)**
- 1 common parameter (σ)
- Better description of the shape

The next steps

- Background PDF $f_{bck}(x)=(1/C_{norm})[re^{\lambda x}+(1-r)]$, $N_{par}=2$ ✓

- Expected shape of data (signal + background) is for each Toy MC fitted with $f=k\cdot f_S+(1-k)\cdot f_{BDK} \Rightarrow N_S=k\cdot \int f\, dm$ integration range *105-135 GeV*

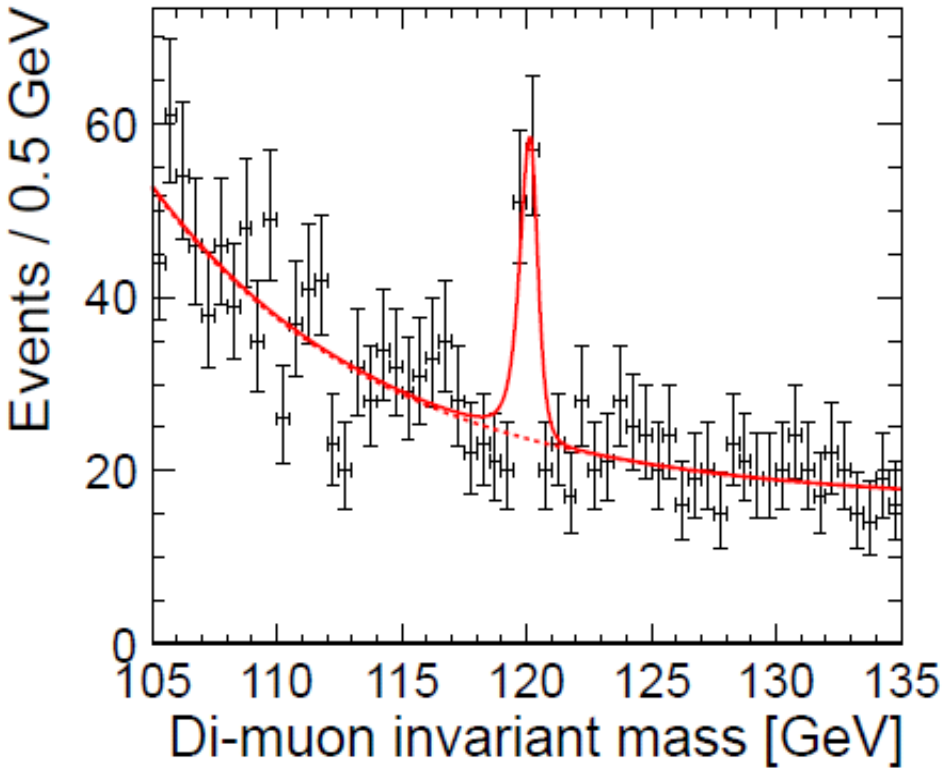
- Make pull distributions to estimate N_S uncertainties and proves the shape descriptions with PDFs

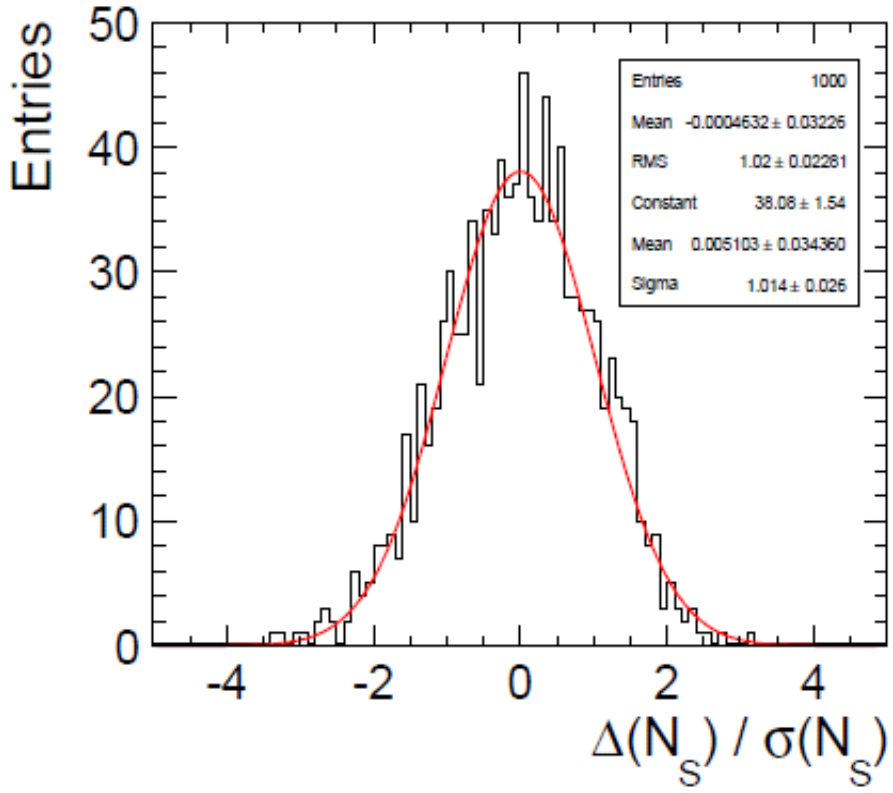
- Include additional backgrounds ($\gamma\gamma\rightarrow\mu\mu$, $\gamma\gamma\rightarrow hadrons$)

- Check the impact of p_T resolution as it affects the shape(width) of the di-muon invariant mass distribution

- Study impact on forward electron tagging (electron veto) that would mainly affect $e^+e^-\rightarrow e^+e^-\mu^+\mu^-$

An example of the invariant mass fit from 3 TeV





$\sigma_{ww\_fusion} \cdot BP(H \to \mu^+\mu^-)$ estimated with the average statistical error of ~ 23%

from 1000 Toy MC at 3 TeV

Conclusions

- There is strong motivation in physics BSM in BR measurement of the rare $H \rightarrow \mu^+\mu^-$ decay at CLIC

- To complete the Higgs study at CLIC we are looking into 1.4 TeV case, introducing some improvements along the way (i.e description of signal PDF)

- Progress is quite fast (we started the analysis in January)

- End of June might be realistic to complete the work

FCAL Plans

- Test-beam - Operation and analysis in 2014 campaign

{ Strahinja - DAQ and test-beam data analysis}

{ Ivan- pixel telescope operation and test-beam data analysis}

- Simulation studies - looking for a new topic (Mila) - to be discussed
- Meetings: LCWS2013 (Mila, *Luminosity measurement at 500 GeV and 1 TeV ILC*, Ivanka, *Light Higgs decay to μμ at 1.4 TeV CLIC*, Strahinja, *Precise luminosity measurement in the forward region at CLIC*)
- 2 JINST papers (1 accepted JINST_008P_0313, 1 submitted JINST 016P 0413)