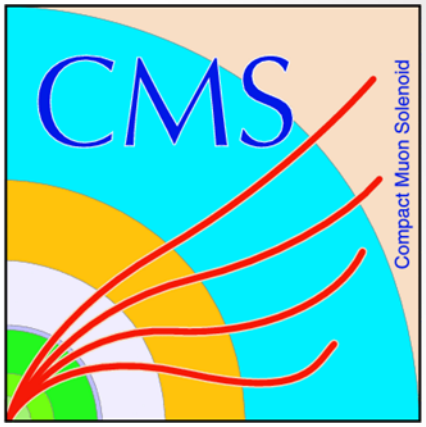


Higgs search in the $H \to \tau\tau \to \mu\mu$ channel

Agni Bethani on behalf of the DESY Hamburg-KIT group

5th Annual Workshop of the Helmholtz Alliance

7th Dec 2011, Bonn

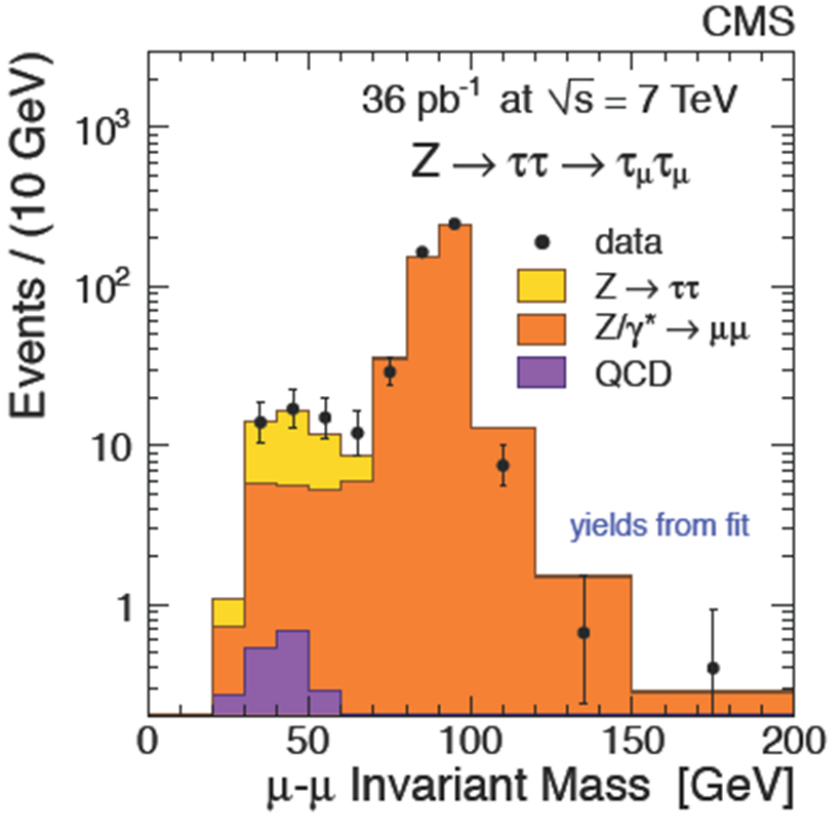
In this talk…

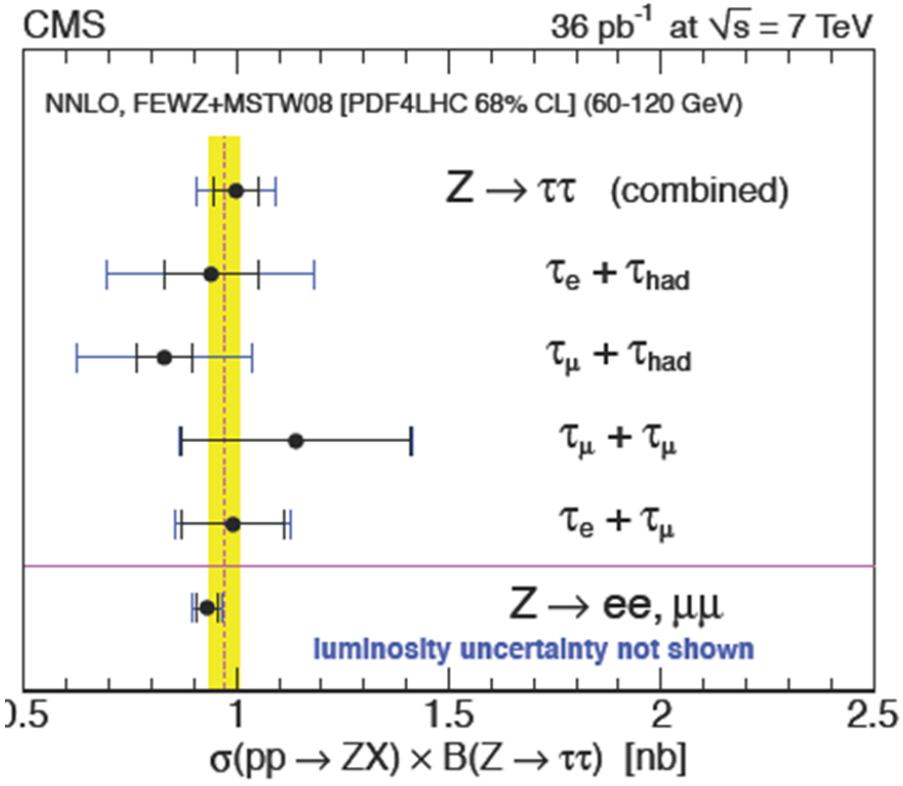
- Z→ττ→μμ analysis
  - Results
- H→ττ→μμ analysis
  - Event selection
  - Likelihood selection
  - Background estimation
  - Embedding method
  - Limits
- Summary

Z→ττ production σ measurement

- Z→ττ→μμ combined with other channels
  - σ= 1.14±0.27(stat)±0.04(syst.)±0.05(lumi.)
- Combined measurement
  - σ= 1.00±0.05(stat)±0.08(syst.)±0.04(lumi.)

Published
CMS-EWK-10-013,
JHEP08(2011)117





H→ττ→μμ analysis

- Total analysed luminosity: L=2.05 fb^{-1}
- Trigger selection:

Trigger	Luminisity, fb^{-1}
HLT_IsoMu17	1.38
HLT_Mu13_Mu8	0.67

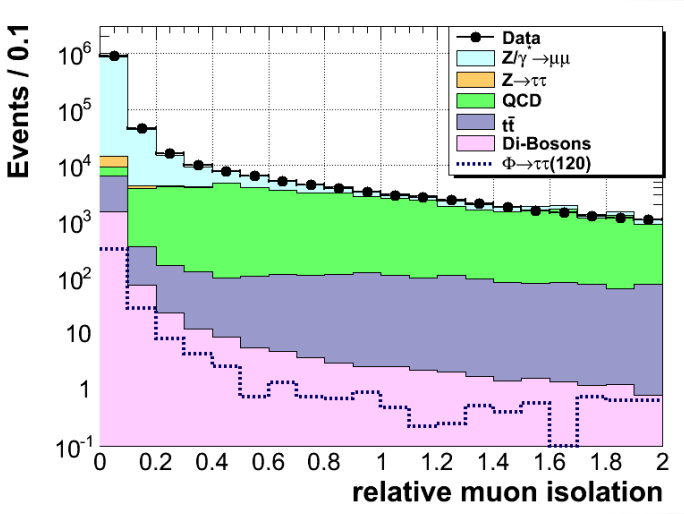
- MC samples:

Process	Generator
DY→ll	Madgraph+TAUOLA
TTJets	Madgraph
WJets→lν	Madgraph
QCD	Pythia
SUSY BBH→ττ	Powheg + Pythia+TAUOLA
SUSY /SM gg→H→ττ	Powheg + Pythia+TAUOLA
VBF H→ττ	Pythia

WORK IN PROGRESS

Muon Selection

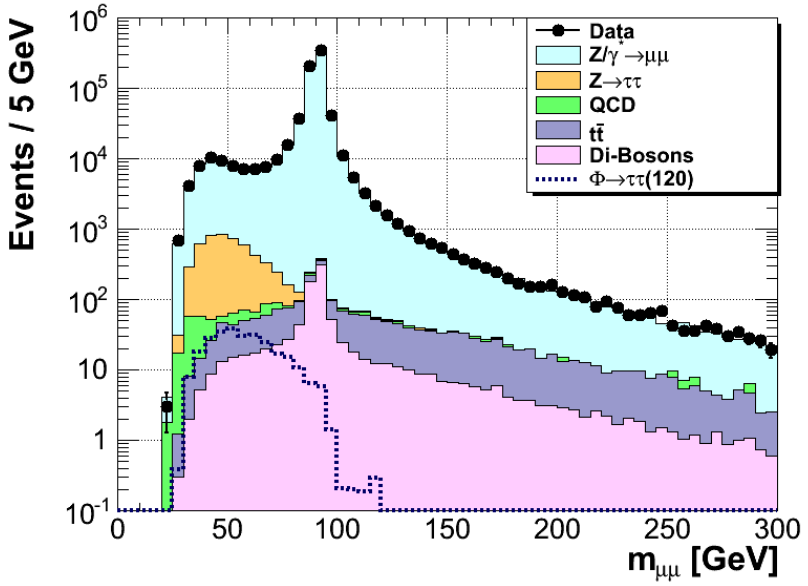
- Opposite sign muons
- Requirements for “good” PV and muon track quality
- $|\eta|<2.1$ (2.4) for the leading (sub-leading) muon
- p_T >20 (10) GeV for the leading (sub-leading) muon
- $\Delta\Phi>2$ (rejects QCD events)
- Isolation <0.1 (0.15) for muons with p_T >(<)15GeV/c ($\Delta R<0.4$)
- $Iso_{\mu}^{\mathrm{PF}} = \frac{\sum(p_T^{charged}+p_T^{\gamma}+p_T^{neutral})}{p_T^{\mu}}$



WORK IN PROGRESS

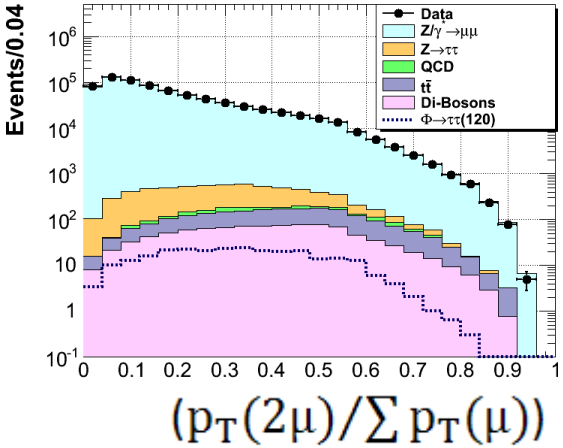
Likelihood selection

- Preselected dimuon event sample is dominated by DY background
- MVA technique
  - $Prob(j) = \prod_{i=1}^{m} f(j, x_i)$
  - $L(j) = \frac{Prob(j)}{\sum_{k=1}^{3} Prob(k)}$
- 3 event classes (j)
  - $Z/\gamma^{*} \rightarrow \mu\mu$
  - $Z \rightarrow \tau\tau$
  - $\Phi \rightarrow \tau\tau \rightarrow \mu\mu$ signal
- Discriminating variables (x_i)

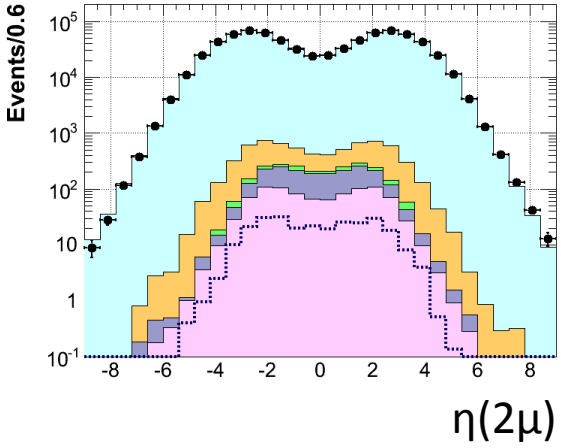


WORK IN PROGRESS

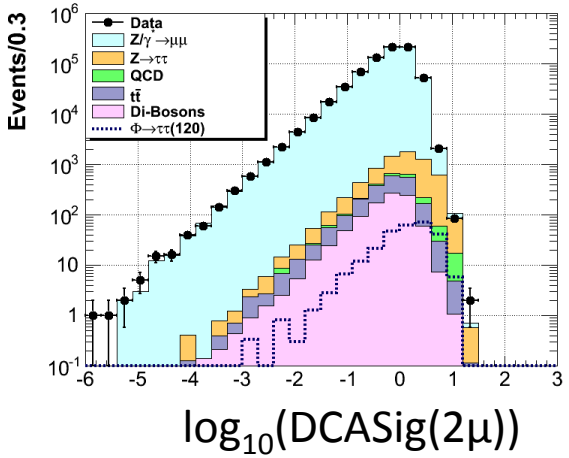
Discriminating variables



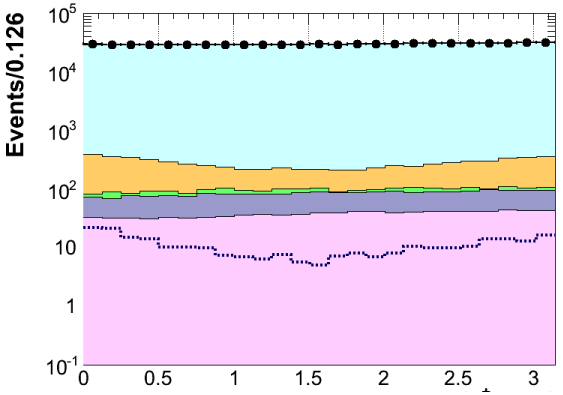
$(p_T(2\mu)/\sum p_T(\mu))$



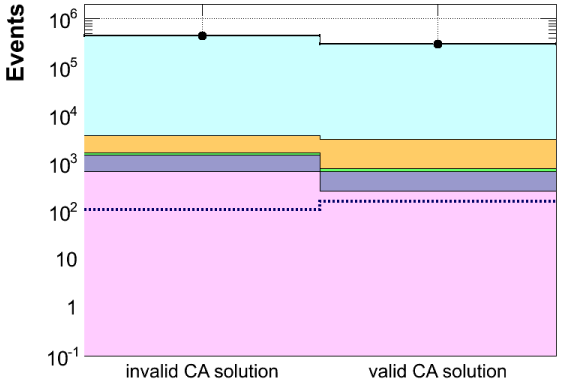
η(2μ)



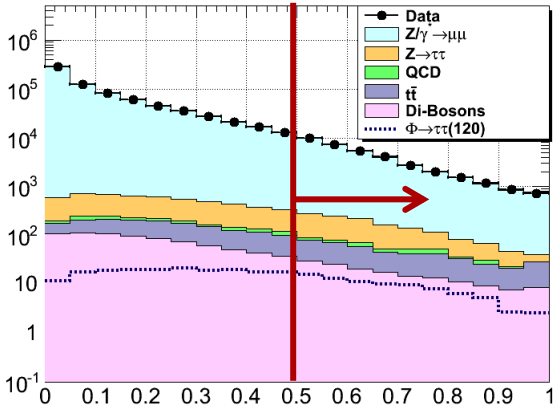
$\log_{10}(\text{DCASig}(2\mu))$



$\Delta\phi(p_T(\mu+),\text{MET})$



Validity of CA solution

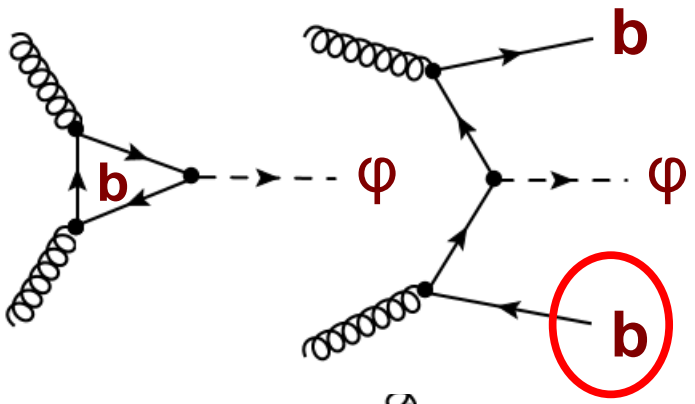


Likelihood

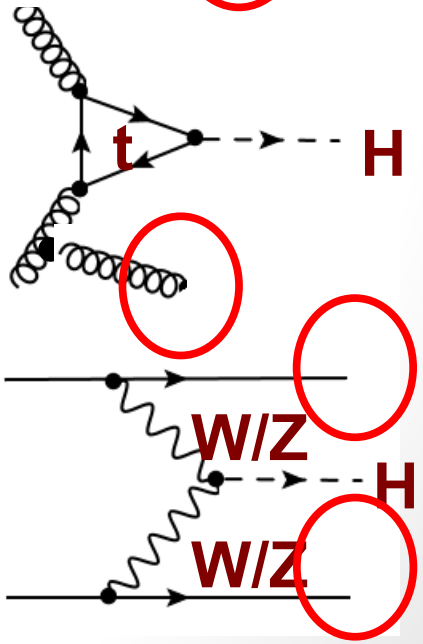
WORK IN PROGRESS

Event Categories

- Jet related variables are exploited in order to identify different Higgs production mechanisms
- Event Categorisation (MSSM)
  - bbΦ production (MSSM)
    - B-Tag (at least one b jet)
    - No B-Tag (no b jets)



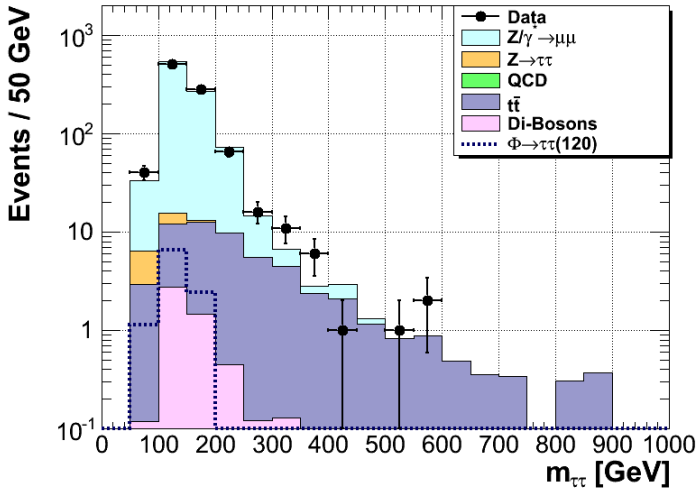
- Event Categorisation (SM)
  - Vector boson fusion Higgs production (VBF)
  - Boosted Higgs (NEW!)
  - One or no jets – Gluon fusion

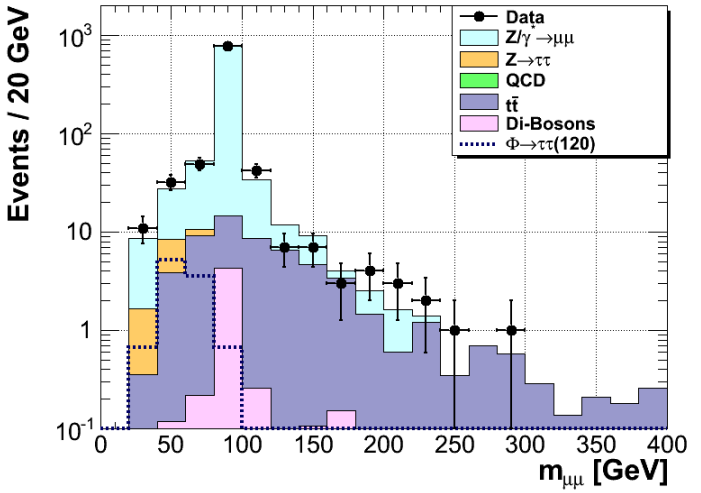


WORK IN PROGRESS

SVFit ditau mass reconstruction

- Secondary Vertex Fit (SVfit) is a novel algorithm for tau pair invariant mass reconstruction that utilizes kinematics of tau decay and reconstructed missing transverse momentum. (introduced by CMS)
- This variable together with the visible dimuon mass are used for the statistical analysis. (In the form of 2D distributions)

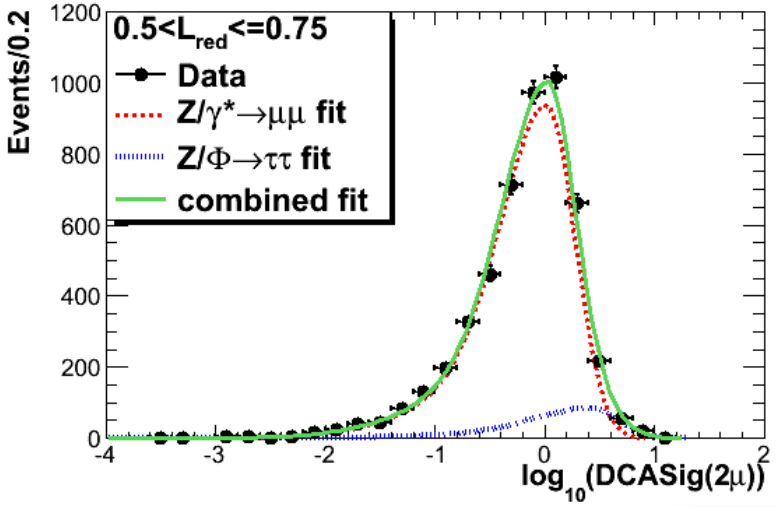




WORK IN PROGRESS

DY background evaluation

- By exploiting the difference in the shapes of the intermuon DCA significance between:
  - $Z/\gamma^* \rightarrow \mu\mu$
  - $Z \rightarrow \tau\tau$ and $\Phi \rightarrow \tau\tau \rightarrow \mu\mu$ signal
- The DY background is estimated in 3 dimuon mass regions
  - $m < 70\ GeV/c^2$ ($Z \rightarrow \tau\tau$ contribution)
  - $70\ GeV/c^2 < m < 130\ GeV/c^2$ (Z peak)
  - $m > 130\ GeV/c^2$

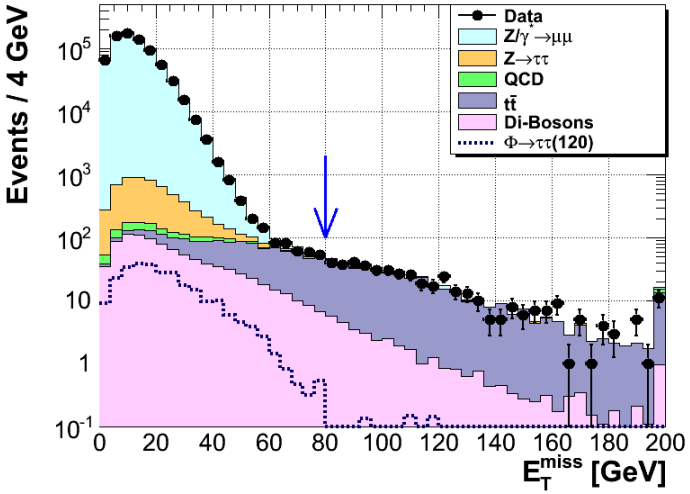


- New "reduced" likelihood constructed by the same variables except DCA significance
- 4 Bins of L_{red} are considered
  - In the range (0,1)-step 0.25
- DCA significance distributions are fitted in the $[L_{red}, M_{\mu\mu}]$ bins
  - $Z/\gamma^* \rightarrow \mu\mu$ is parametrised in the Z peak ($80\ GeV/c^2 < m < 100\ GeV/c^2$)
  - $Z \rightarrow \tau\tau$ and $\Phi \rightarrow \tau\tau \rightarrow \mu\mu$ signal parametrisation is taken from MC

WORK IN PROGRESS

TTBar background evaluation

- TTBar is extrapolated from control region dominated by TTBar background
  - MET> 80 GeV
  - After preselection
  - Purity > 97%
  - Fits of DCASig(2μ) for TTBar
    and heavy resonance decays
  - Templates derived from MC
  - Normalisation for the TTBar contribution
    extracted from the fit



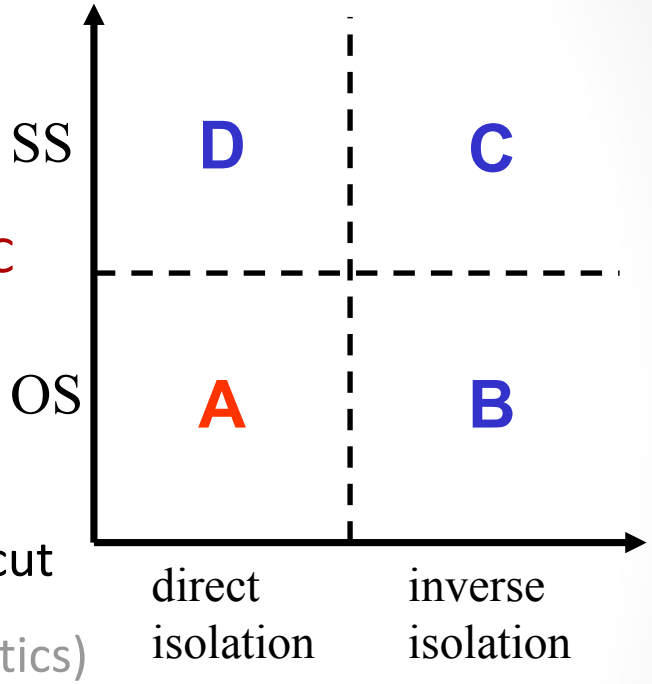
WORK IN PROGRESS

QCD Background evaluation

- The A,B,C,D method:
  - A: signal region
  - If after selection opposite sign

  and same sign have same properties: A=B·D/C
  - Direct Isolation <0.1 (0.15) for muons with p_T >(<)15GeV/c
  - Inverse Isolation > 0.5
- The numbers below refer to Inverse Isolation cut

(The Direct Isolation cut suffers from low statistics)



	Data OS/SS	QCD MC OS/SS
Lkh>0.5	1.76+/-0.03	1.80+/-0.04

	Purity
OS	98.3+/-0.3%
SS	98.3+/-0.2%

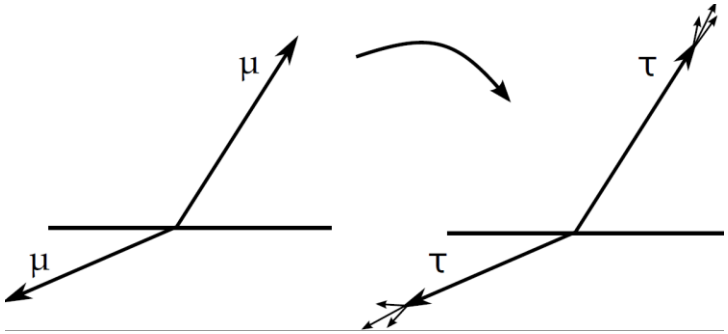
QCD events in the final sample: 69.2 +/- 11.9

WORK IN PROGRESS

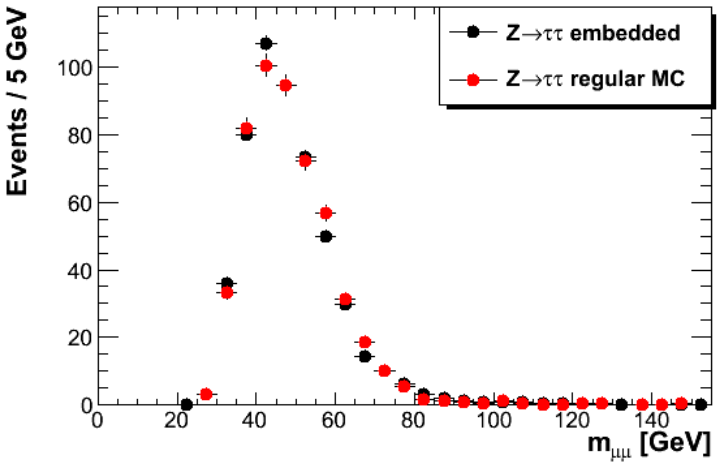
Embedding method

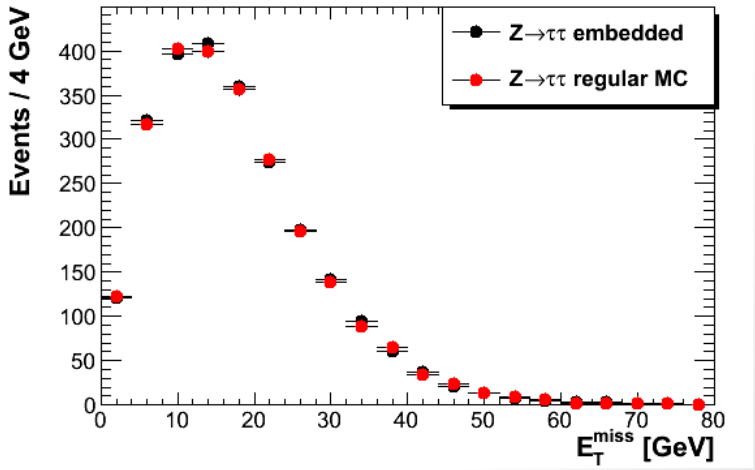
Thanks to Armin Burgmeier and Manuel Zeise

- In a Z→μμ data the two muons are replaced with simulated taus . (Method implemented in CMS by the KIT group)



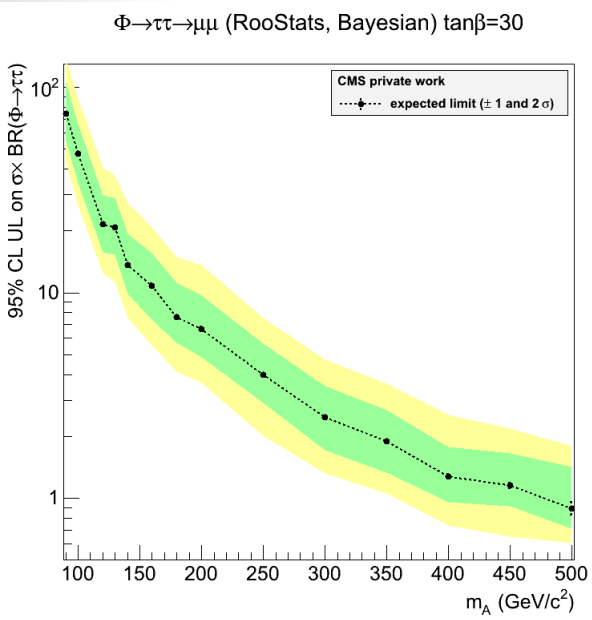
- $Z \rightarrow \tau_\mu \tau_\mu$ embedded sample is used to model mass shapes





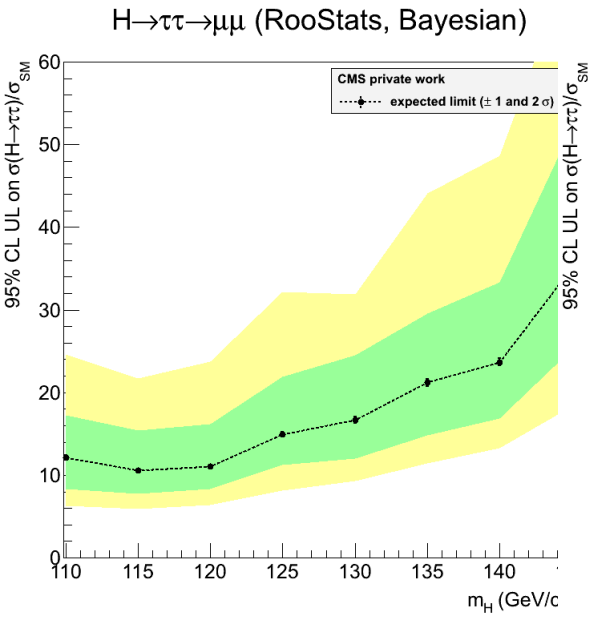
WORK IN PROGRESS

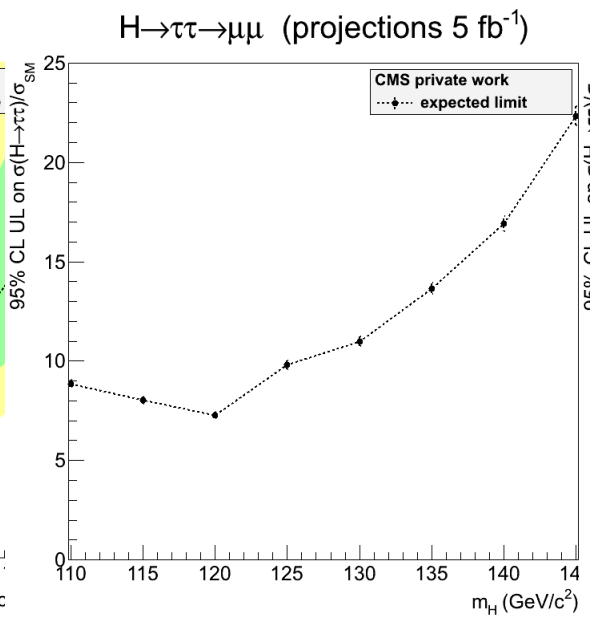
Limit setting

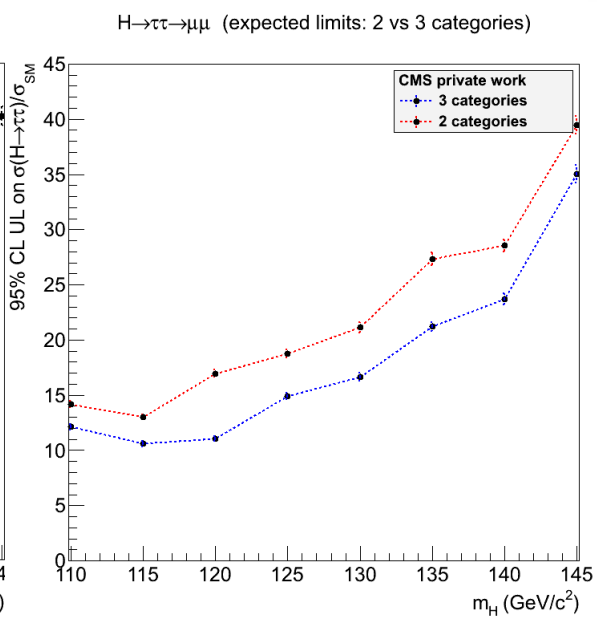


- Statistical interpretation of the data is done by using the **Bayesian** limit setting technique and RooStat software
- With only half the luminosity of 2011 data considered, we can set sensitive limits and contribute significantly to the Higgs searches

Significant gain obtained by including the Boosted Higgs category in our analysis







WORK IN PROGRESS

Summary

- H→ττ→μμ analysis is performed for 5 categories of events:
  - Event Categorisation (MSSM)
    - B-Tag
    - no B-Tag
  - Event Categorisation (SM)
    - Vector boson fusion
    - Boosted higgs (NEW!)
    - One or no jets – Gluon fusion
- Background contributions are evaluated in data driven ways or using the embedding method
- Limits for the Higgs boson production are set

Thank you for your attention

Backup

Jets and B-Tagging

- Jet related variables are exploited in order to identify different production mechanisms
- Event Categorisation (MSSM)
  - bbΦ production (MSSM)

B-Tag category	no-BTag category
≥ 1 b-jets	no b-jets
< 2 jets with p_T >30 GeV/c	< 2 jets with p_T > 30 GeV/c

- Event Categorisation (SM)
  - Vector boson fusion
  - Boosted higgs (NEW!)
  - One or no jets – Gluon fusion

WORK IN PROGRESS

SM Higgs Boson

Vector Boson Fusion Analysis (VBF)

- Event selection
  - at least two jets with $p_T > 30$ GeV/c and $|\eta|<4.5$
  - jets in opposite hemispheres: $\eta_1\eta_2<0$
  - $m_{jj} > 400$ GeV/c^2
  - $|\Delta\eta_{jj}|>4.0$
  - no jets with $p_T > 30$ GeV/c in the rapidity gap between the two leading jets
- Muon selection
  - The higgs produced may have very high p_T
  - $|\Delta\Phi|$ cut dropped – $m_{\mu\mu} > 20$ GeV/c instead

WORK IN PROGRESS

SM Higgs Boson

Boosted Higgs Analysis

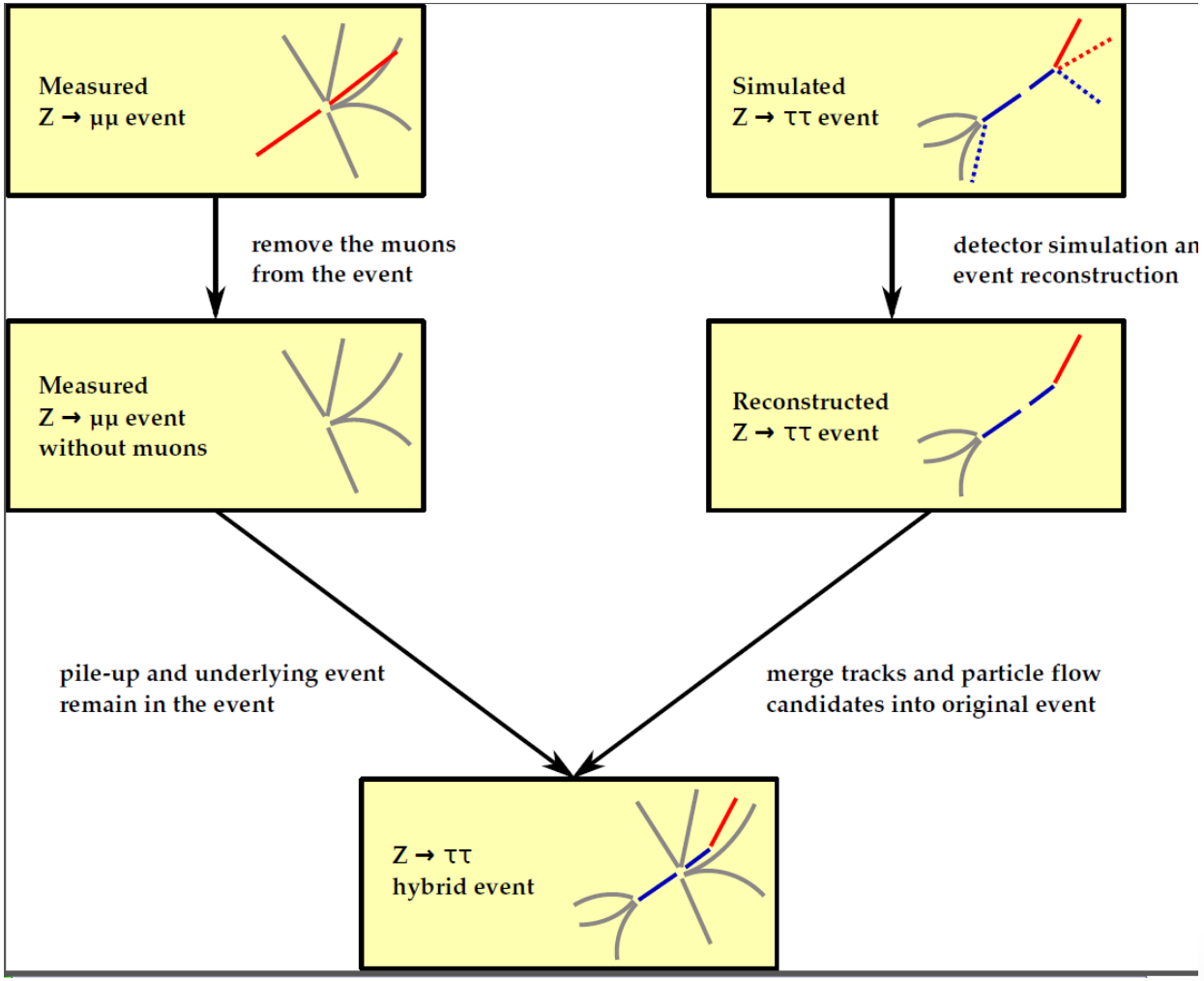
- Highly boosted Higgs boson
- May happen :
  - in the Higgs associated production with t,Z or W
  - gluon fusion with initial radiation of hard gluon
- Events with only one jet with: p_T >150 GeV/c

One or no jets

- Higgs produced by gluon fusion
- Events with 0 or 1 jet with: 30 GeV/c< p_T < 150 GeV/c

WORK IN PROGRESS

Embedding method



WORK IN PROGRESS