MSSM $bb(H \to bb)$ semileptonic

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Outline

1. Analysis strategy
2. Trigger
3. Selection
4. Background
   - Btag probability matrices
   - HyperBall
   - B-Matrix vs HyperBall
5. Systematics
   - Background Normalization Systematics
6. Sensitivity
7. Summary

Documentation

- AN AN-11-428
- PAS HIG-12-027
- HN HIG-12-027
- Twiki CMS/HiggsBBbb

Available on the CMS information server **CMS AN AN-11-428**

CMS Draft Analysis Note

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2012/06/07
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Archive Date: 2012/06/06
Archive Tag: trunk

Search for SuperSymmetric Higgs boson states decaying into a pair of b-quarks with semi-leptonic trigger

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Abstract

In this paper the results of a search of neutral SuperSymmetric Higgs particles decaying into pairs of b-quarks, and produced in association with other two b-quarks are presented, using the data corresponding to 4.8 fb^{-1} collected in 2011 with a semi-leptonic trigger by the CMS experiment at the LHC, operating at center of mass energy of 7 TeV. Two different data driven method to predict the background are described, with a combined low statistical and systematical uncertainties. The results are presented in the framework of MSSM.

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PDFAuthor:	S. Lacaprara, U. Gasparini
PDFTitle:	Search for Neutral SuperSymmetric Higgs boson states decaying into a pair of b-quarks at the LHC
PDFSubject:	CMS
PDFKeywords:	CMS, physics, Higgs, beauty

Please also verify that the abstract does not use any user defined symbols

CMS PAS HIG-12-027

DRAFT
CMS Physics Analysis Summary

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Archive Date: 2012/06/05
Archive Tag: trunk

MSSM Higgs production in association with b quarks - semi leptonic

The CMS Collaboration

Abstract

In this paper the results of a search of neutral SuperSymmetric Higgs particles decaying into pairs of b-quarks, and produced in association with other two b-quarks, are presented. The data used, corresponding to 4.8 fb^{-1}, was collected in 2011 with a semi-leptonic trigger by the CMS experiment at the LHC, operating at center of mass energy of 7 TeV. Two different data driven methods to predict the background are described, yielding low statistical and systematical uncertainties. The results are presented in the framework of MSSM.

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PDFAuthor:	S.Lacaprara, U.Gasparini
PDFTitle:	MSSM Higgs production in association with b quarks - semi leptonic
PDFSubject:	CMS
PDFKeywords:	CMS, physics, software, computing

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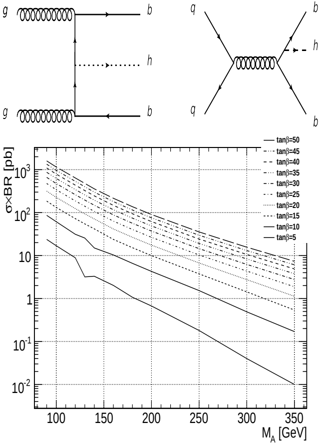
Intro: motivations

- Search for Neutral SUSY Higgs, $H \to b\bar{b}$;
- Large $BR(H \to b\bar{b}) \approx 90\%$
- huge multijet QCD background:
  - Use associate production to reject hadronic background
  - $pp \to b\bar{b}H \to b\bar{b}b\bar{b}$
  - Large σ for large $\tan\beta$
  - $A/H/h$ degeneration increases σ
  - *e.g.* $\sigma_{M=120} \times BR \approx 250\ pb$ for $\tan\beta = 30$
- Compete with $H \to \tau\tau$ channel:
  - larger yield,
  - larger background (QCD),
  - different channel.



Analysis Strategy

- 4 b final state: $H \to bb$ plus additional associated b's
- trigger is critical:
  - Use semi-leptonic (muon) b decay for trigger: muon+jets+b-tagging
- Major irreducible background source is multijet QCD
- Data driven background estimate from bbj sample
  - define signal-poor control sample;
  - B-tagging Matrix method:
    - ⋆ get b/c-fraction of 3rd jet from mass & lifetime fits
    - ⋆ combine with MC b-tagging efficiency to derive B-tag probability
    - ⋆ weight bbj events to estimate number of 3-b-tags in signal region
  - Second approach with nearest-neighbour method (hyperball)
    - ⋆ start from bjj
- Use reconstructed mass of leading jet pair as signal-sensitive variable in final fit
- Use only 2011 data

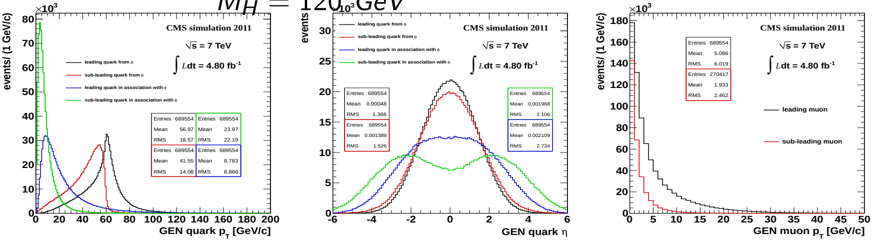
Unblinding strategy

- Define a control region in Data sample, where the expected signal to background ratio is very small, using a suitable discriminator developed in MC samples;
- perform full analysis on MC, including closure test in control and signal region;
- work exclusively on control region for Data
- show only background prediction for Data in signal region
- open the box (signal region) after green light.

Trigger Strategy

- Use semi-leptonic *b* decay for trigger: **muon + jets + b-tagging**

$M_H = 120\,GeV$



Use different trigger Path in 2011 to cope with increasing $\mathcal{L}$

HLT paths	runs	triggers	$\int \mathcal{L}dt$ [pb^{-1}]
Mu12_CentralJet30_BtagIP	163738-165633	3 027 717	180.9
Mu12_DiCentralJet30_BtagIP3D	165970-166967	4 532 555	537.1
Mu12_DiCentralJet20_DiBtagIP3D1stTrack	167039-173198	2 244 550	1108.6
Mu12_eta2p1_DiCentralJet20_DiBtagIP3D1stTrack	173236-176469	1 237 147	652.2
Mu12_eta2p1_DiCentralJet20_DiBtagIP3D1stTrack*	176545-180252	5 690 304	2326.8
All		16 732 273	4805.7

Data Used

$H \rightarrow bb$ Signal selection samples	
Run2011A	/MuHad/Run2011A-May10ReReco-v1/AOD
Run2011A	/MuHad/Run2011A-PromptReco-v4/AOD
Run2011A	/MuHad/Run2011A-05Aug2011-v1/AOD
Run2011A	/MuHad/Run2011A-PromptReco-v6/AOD
Run2011B	/MuHad/Run2011B-PromptReco-v1/AOD

Trigger efficiency samples	
Run2011A	/SingleMu/Run2011A-May10ReReco-v1/AOD
Run2011A	/SingleMu/Run2011A-PromptReco-v4/AOD
Run2011A	/SingleMu/Run2011A-05Aug2011-v1/AOD
Run2011A	/SingleMu/Run2011A-PromptReco-v6/AOD
Run2011B	/SingleMu/Run2011B-PromptReco-v1/AOD

Table: Summary of data samples used in this analysis

Analysis selection

Selections

Baseline selections:

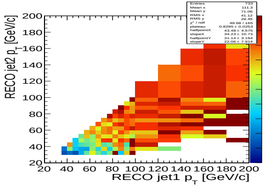
- Trigger
- at least 1 global muon $P_T^{\mu} > 15$ GeV, no isolation required;
- at least 3 jets (PFak5, LooseId) $|\eta| < 2.6$, $P_T > (30, 30, 20)$ GeV
  - $\Delta R_{ij} > 1$ for any pair $_{ij}$ of jets
  - the μ inside one of the two leading jets;

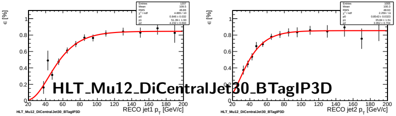
bjj the first jet must have b-tag $CSV > 0.8$

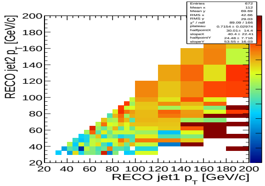
bbj the second jet must have b-tag $CSV > 0.8$

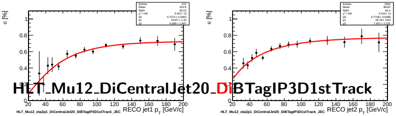
bbb last selection: third jet b-tag $CSV > 0.7$

Trigger Efficiency vs Analysis







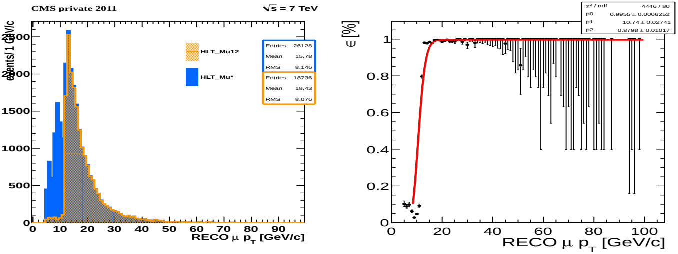


- $\epsilon_{trigger} = \epsilon(\mu) \times \epsilon(hadr)$
- **SingleMu PD**, select all events passing a single muon path.
- Apply selection
- Build Turn on curves vs first and second B-jets Pt:

$$\epsilon = \frac{\text{Hbb path \& sel \& SingleMuHLT}}{\text{sel \& SingleMuHLT}}$$

- Turn-on stable wrt SingleMu threshold
- shown for single and double online b-tag paths

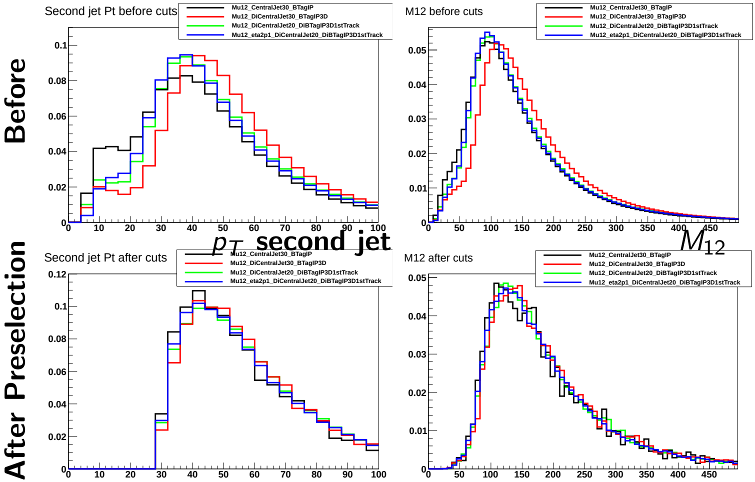
Muon “leg”: $\epsilon(\mu)$



$\epsilon(\mu)$

- consider HLT_Mu12 path
- Computed on data using lower (pre-scaled) singleMu trigger path
- as a function of reconstructed muon p_{T}
- for $p_t > 15$ already in plateau $\gtrsim 99\%$.

Trigger paths vs Analysis



After pre-selection cut, distributions for different paths are similar

Background determination: b-tag parametrization

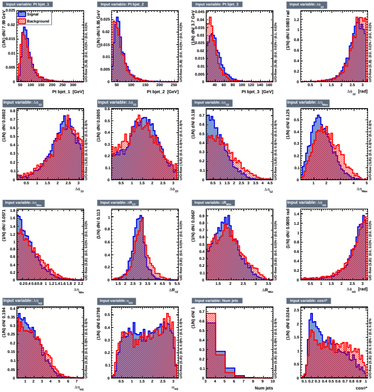
- Define a control region using a likelihood ratio discriminator using the most discriminating variables (depends on M_H)
- Build B-tagging probability matrices $P^{3^{rd} jet}_{b-tag}(\dots)$ in control region for third jet, as a function of 3^{rd} jet and event parameters;

$$P^{3^{rd} jet}_{b-tag}(\dots) = \epsilon_b \cdot f_b + \epsilon_c \cdot f_c + \epsilon_l \cdot f_l$$

  - b-tagging efficiencies $\epsilon' s$ from MC $\epsilon = \epsilon(E_T, |\eta|, N_{trk})$
  - flavour fractions $f_{b,c,l}$ from Data parametrization see next slides
- Estimate any bbb distribution $F(x; bbb)$ for variable x in signal region starting from same distribution for bbj;

$$F(x; bbb) = F(x; bbj) \otimes P^{3^{rd} jet}_{b-tag}(\dots)$$

Discriminator: Low Mass $M_H \leq 200\ GeV$



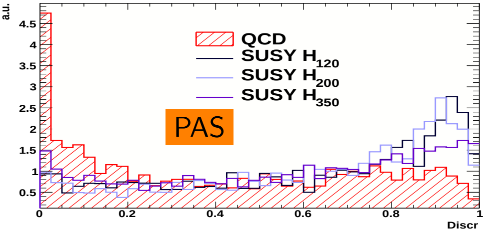
Likelihood ratio

$$Discr = \frac{\Pi_i p_i^{(signal)}(x_i)}{\Pi_i p_i^{(signal)}(x_i) + \Pi_i p_i^{(QCD)}(x_i)}$$

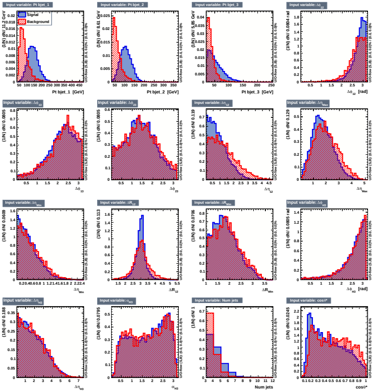
Training $M_H = 120, 130, 140$

Used for test up to $M_H \leq 200$

also shown response for higher masses



Discriminator: High Mass $M_H > 200\ GeV$

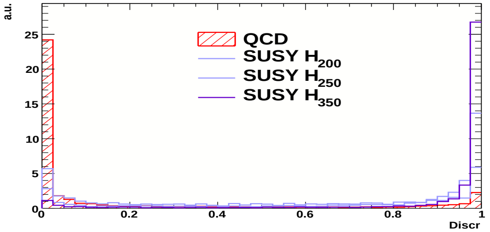


Likelihood ratio

$$Discr = \frac{\Pi_i p_i^{(signal)}(x_i)}{\Pi_i p_i^{(signal)}(x_i) + \Pi_i p_i^{(QCD)}(x_i)}$$

Training $M_H = 250, 300, 350$

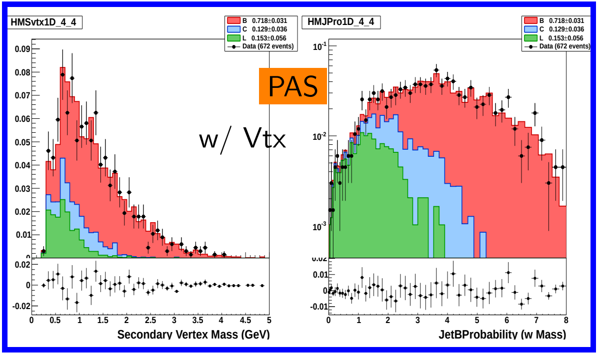
Used for test from $M_H > 250$

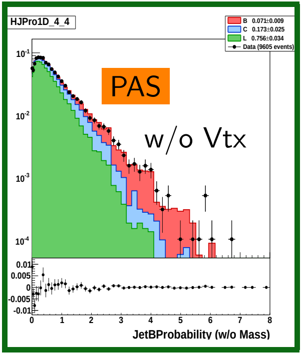


Heavy quark fraction

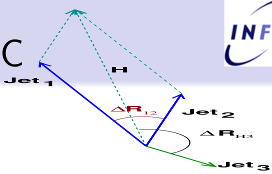
Consider Mass@Vertex and JetBProbability for third jet;

- build distribution templates from MC QCD, for B, C and Light;
- fit third jet distributions using templates and get $F_{b,c}$;
  - use only JetBProbabilty if Mass@Vertex not available.





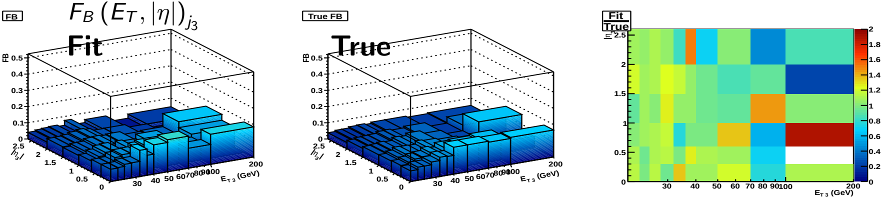
F_B parametrization & fit results in MC



$$F_B = F_{B,C}\left(E_T^{(j_3)}, \left|\eta^{(j_3)}\right|\right) \times F_{B,C}\left(\Delta R_{H,j_3}, \Delta R_{j_1,j_2}\right)$$

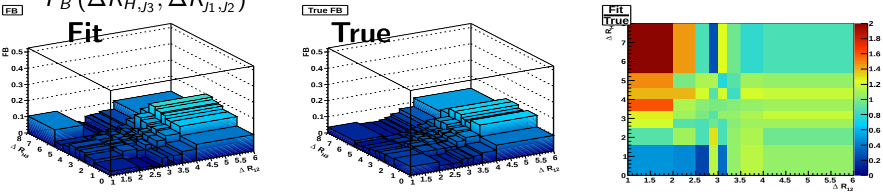
assuming no correlation. Second factor only for shape.

$F_B\left(E_T, |\eta|\right)_{j_3}$



Overall bias for F_b around $\approx +6\%$

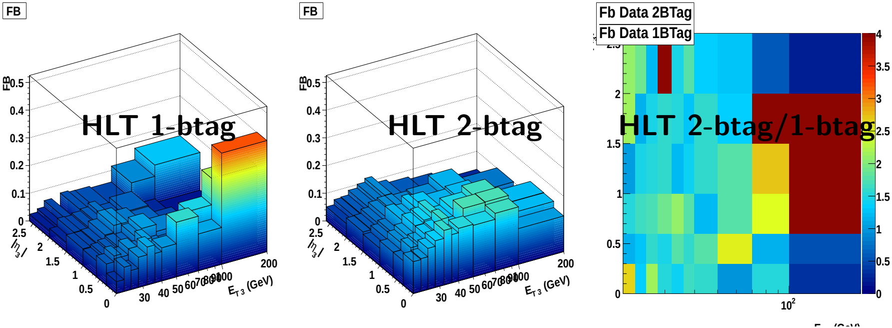
$F_B\left(\Delta R_{H,j_3}, \Delta R_{j_1,j_2}\right)$



F_B Fit results Data (control region)

for Data, fit separately single B-tag and double B-Tag HLT paths.

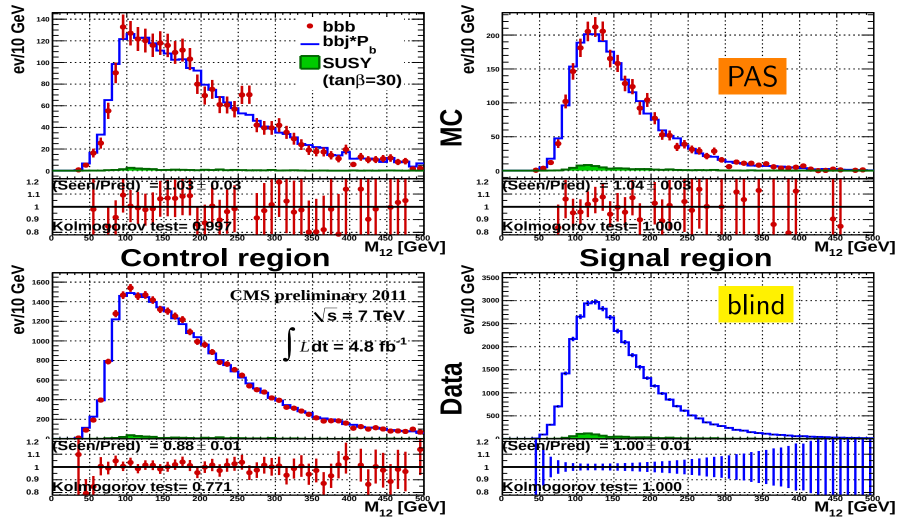
$$F_B\left(E_T^{(j_3)}, \left|\eta^{(j_3)}\right|\right)$$



Enhancement of b in third jets, due to the online double b-tag trigger, is clearly visible.

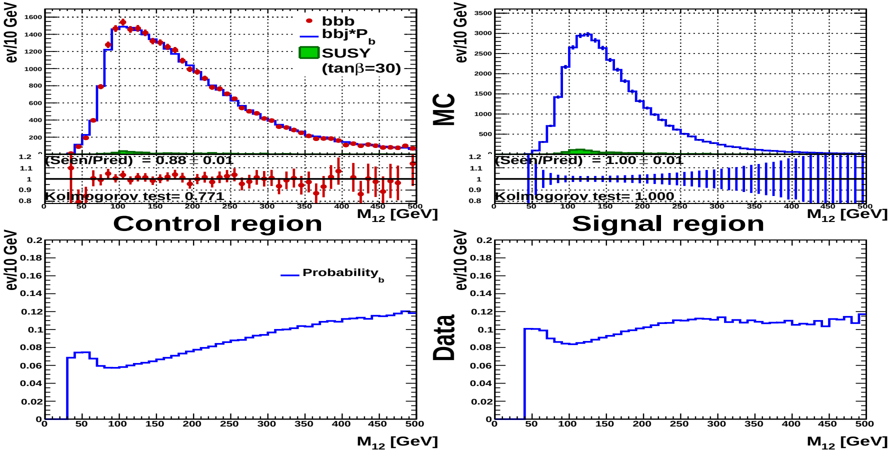
M_{jj} prediction vs bbb in MC and Data

in control and signal region: Low Mass ($M_H \leq 200$) susy $M_H = 120$ GeV



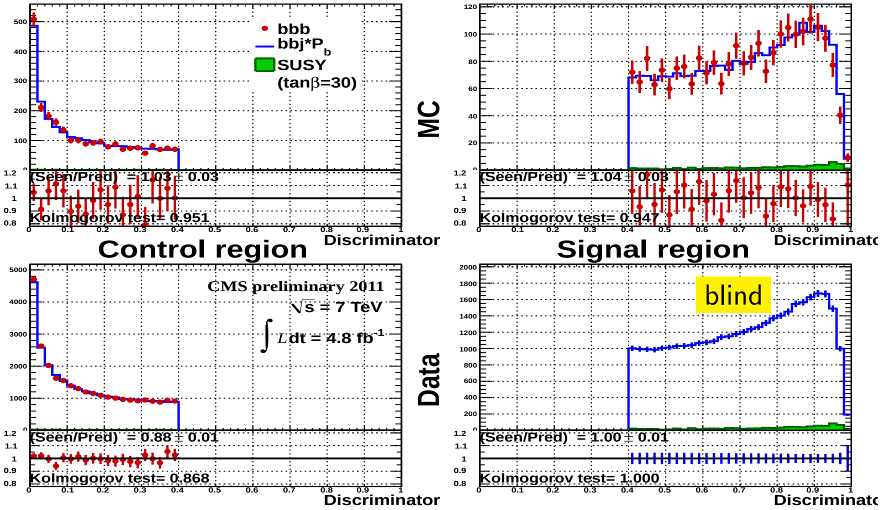
For Data (control region) shape fine, normalization $\sim 0.88\%$

Third jet B-tag probability: Data



Discriminator prediction vs *bbb* in MC and Data

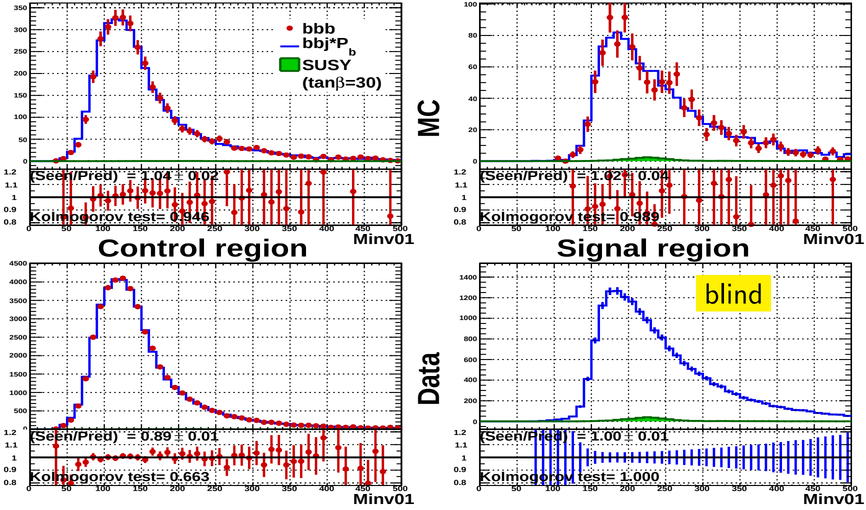
in control and signal region: Low Mass ($M_H \leq 200$) susy $M_H = 120$ GeV



Prediction stable wrt discriminator other variables in backup

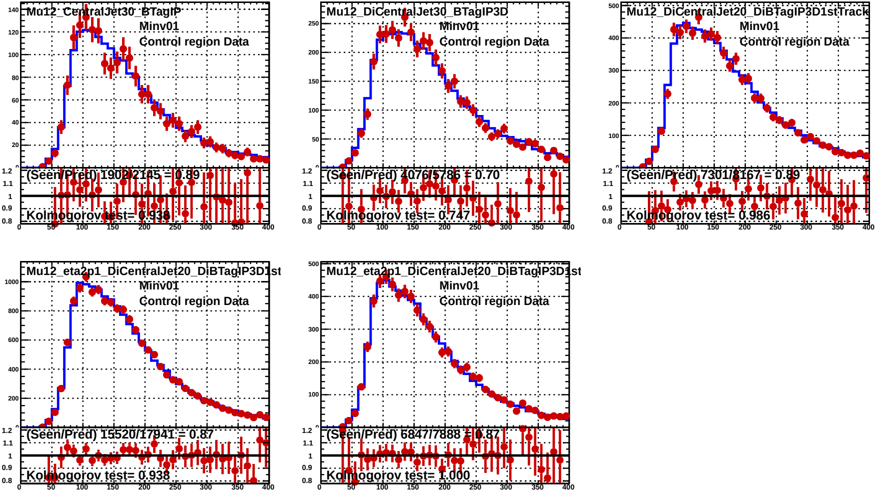
M_{jj} prediction vs *bbb* in MC and Data

in control and signal region: High Mass ($M_H > 200$) susy $M_H = 250$ *GeV*



For Data (control region) shape fine, normalization $\sim 0.89\%$

Data: M_{jj} prediction for different HLT paths in control region: Low Mass ($M_H \leq 200$)



Shape fine for all HLT paths

Hyper Ball

Second approach, independent background estimation.

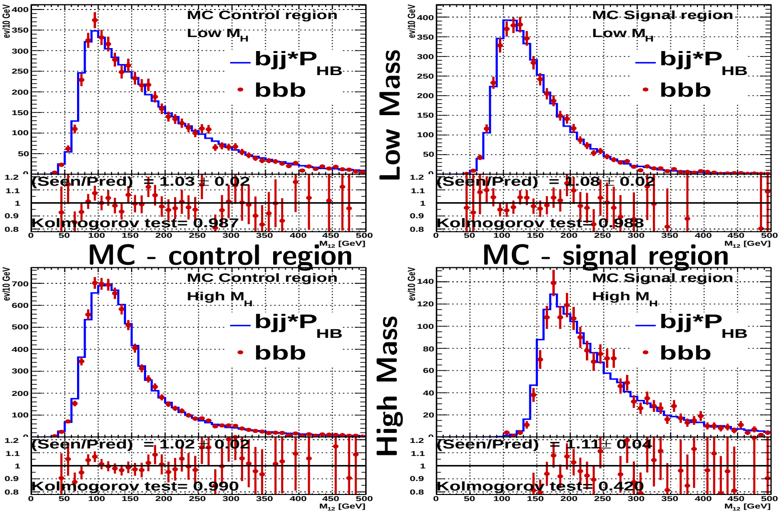
General idea

- Start from *bjj* sample, control region;
- For each event in $(bjj)_{CR}$ select a set of *similar* events $\mathcal{O}(100)$ from a large training sample $\mathcal{O}(500\,000)$
- Compute the fraction f of these events passing full selection (bbb);
- *similarity* is defined by *distance* between events in hyperspace $d = \Sigma_i^n \left(w_i \left(x_i - y_i\right)\right)^2$ (hence the name)
  - with x_i, y_i jets or event variables (p_T, η, $\Delta\phi_{ij}$, ...): total of 14 variables used;
  - w_i weight to account for different variable values and for variability of f vs a given variable;
  - subtleties: w_i tuning, which variables to consider, how many events in training sample, events near the boundary of variables domain, ...
  - Very CPU intensive!

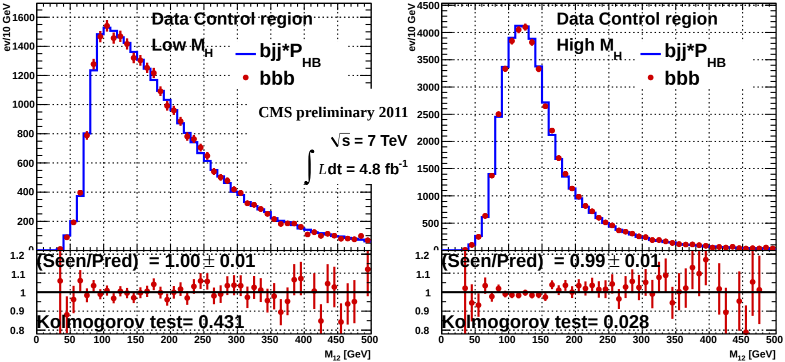
$$F(x; bbb) = F(x; bjj) \otimes f$$

Hyper Ball: results on QCD MC

Closure test



Hyper Ball: results on Data: Control region

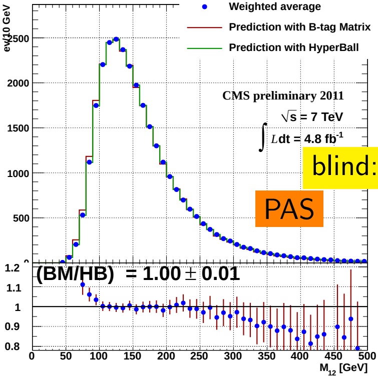


Very good closure for control region both in low and high mass range

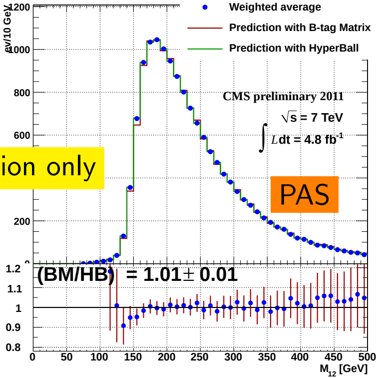
Comparison of B-Matrix and HB prediction

In signal region

Low Mass $M_H < 200\ GeV$



High Mass $M_H > 200\ GeV$



blind: prediction only

- Absolute prediction, **NOT** normalized
- weighted average as combined prediction;
- use comparison as systematic error on shape, unfolding the statistical one (*pdg* recipe);

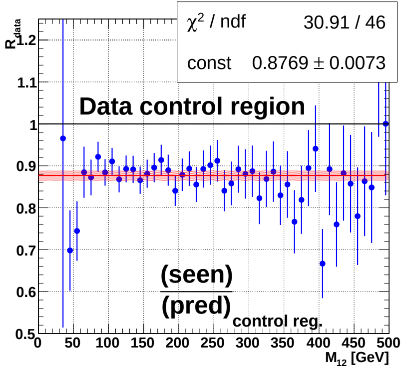
Systematics

- Trigger syst: $\approx 3 - 5\%$ from data driven ϵ estimate;
- Physics object syst:
  - B-tagging eff. BTV-12-001 $\approx 4\%$ per BJet: $\approx 12\%$ for three jets.
  - JEScale $^{+2.5}_{-3.1}\%$
  - JEResolution $\pm 1.9\%$
  - Mu momentum scale $\approx 0.2\%$ and resolution $\approx 0.6\%$
- pdf For $M_H = 120\ GeV$: $^{+2.5}_{-2.7}\%$; for $M_H = 250\ GeV$: $^{+4.7}_{-4.4}\%$;
- Integrated Lumi syst: $\approx 2.2\%$
- Background normalization syst $\approx 5\%$ (see next slides):

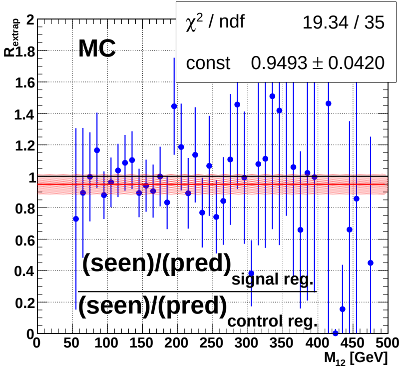
Background Systematics

- Two major source of normalization systematics for the predicted *bbb* in signal region:
  1. Systematics from *bbb* prediction from DATA control region
     - ⋆ compare *bbb* and prediction in DATA control region;
     - ⋆ use normalization in signal region;
     - ⋆ use fit error as systematics;
  2. Systematics due to extrap. from control to signal region from MC
     - ⋆ get ratio of ratios from MC (signal/control) and fit it;
     - ⋆ use fit results to correct extrapolation bias;
     - ⋆ and fit errors to estimate systematics for extrapolation;
- in both cases, a flat ratio is found, so overall systematics, not bin per bin.

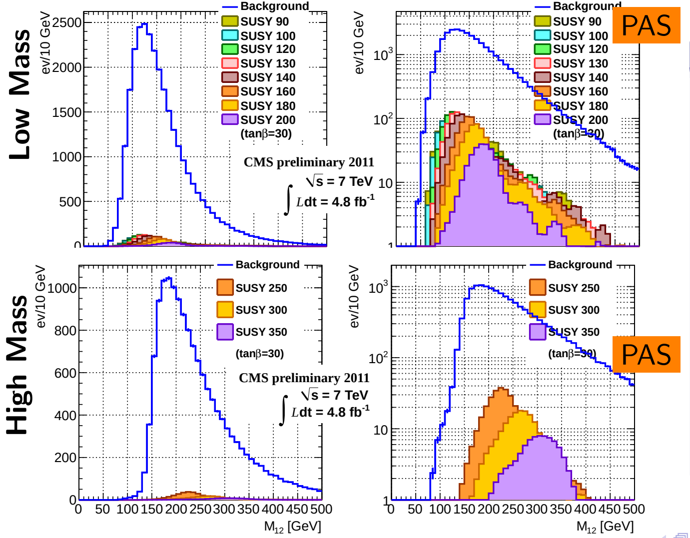
[Data control region]



[MC]



Final prediction and signal ($\tan\beta = 30$)

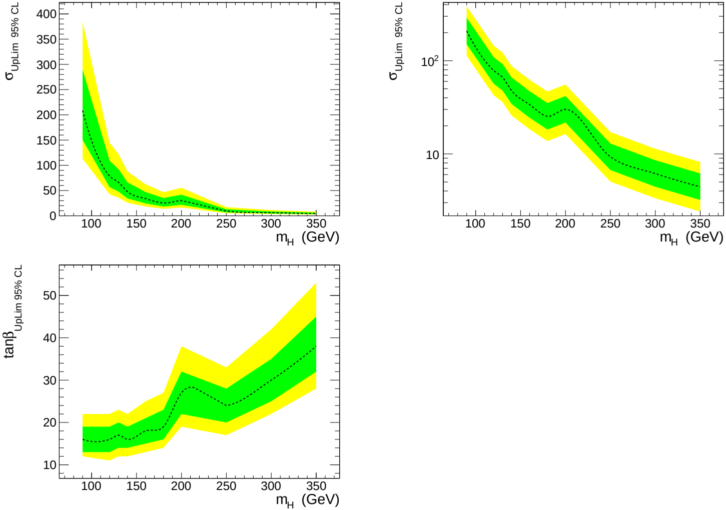


some number

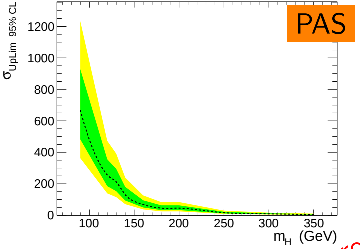
$M_H = 120$
in $[-2\sigma, +2\sigma]$
S=590 B=14554
S/B=1/25

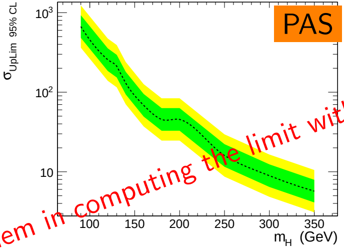
$M_H = 250$
in $[-2\sigma, +2\sigma]$
S=260 B=9600
S/B=1/37

Sensitivity: only statistical errors

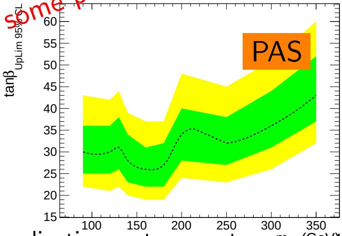


Sensitivity: stat + syst errors





WARNING: we still have some problem in computing the limit with full systematics



the 4.5% background normalization syst seems to worsen the limit too much

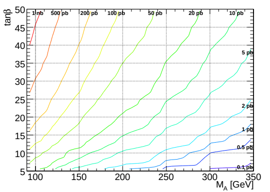
Summary

- Search of MSSM neutral higgs decaying into $b\bar{b}$ with associated $b\bar{b}$ production and semileptonic trigger;
- Two independent data driven methods to estimate QCD background, with remarkable agreement in prediction;
- expected sensitivity is interesting;
  - the analysis can be repeated with 2012 data, where a dedicated trigger is collecting data;
  - other possible improvement: Multi-Variate analysis, b-jet energy regression, ...
- We'd like to have a look to what is under the hat, in the signal region

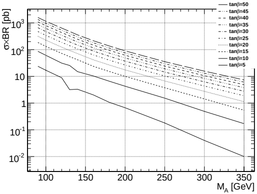
We are asking the pre-approval from the Higgs group

BACKUP

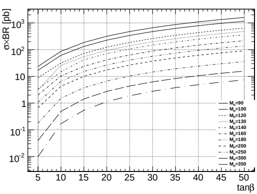
cross-section



(a) $\sigma \times BR$ vs $(M_A, \tan\beta)$



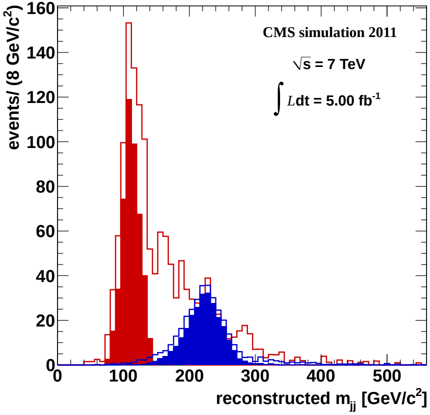
(b) $\sigma \times BR$ vs M_A



(c) $\sigma \times BR$ vs $\tan\beta$

Figure: (a) MSSM neutral higgs production cross section times branching ratio for $b\bar{b}H$ associated production at $\sqrt{s} = 7\ TeV$ and $H \to bb$ decay, as a function of M_A and $\tan\beta$, taking into account the mass degeneration. (b) Same as (a) as

Signal M_{12}


CMS simulation 2011
√s = 7 TeV
∫ Ldt = 5.00 fb⁻¹
events/ (8 GeV/c²)
reconstructed m_jj [GeV/c²]
0
100
200
300
400
500
20
40
60
80
100
120
140
160

PU reweight

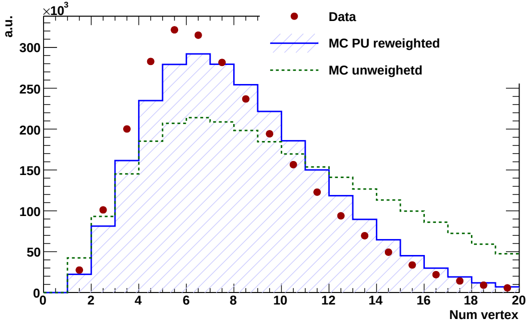


Figure: Reconstructed number of primary vertex in MC simulation with original and reweighted PileUp distribution compared to that found in 2011 Data.

MC samples

Background Processes		
Description	Dataset Name	$\int \mathcal{L}dt$ $[fb^{-1}]$
QCD (μ enriched)	/QCD_Pt-20_MuEnrichedPt-15_TuneZ2_7TeV-pythia6	0.296
$t\bar{t} + jets$	/TTJets_TuneZ2_7TeV-madgraph-tauola	423
Signal Processes $bbH \rightarrow bbbb$		
$m_H = 90$ GeV	/SUSYBBHToBB_M-90_7TeV-pythia6-tauola	1.64
$m_H = 100$ GeV	/SUSYBBHToBB_M-100_7TeV-pythia6-tauola	2.29
$m_H = 120$ GeV	/SUSYBBHToBB_M-120_7TeV-pythia6-tauola	4.29
$m_H = 130$ GeV	/SUSYBBHToBB_M-130_7TeV-pythia6-tauola	5.41
$m_H = 140$ GeV	/SUSYBBHToBB_M-140_7TeV-pythia6-tauola	3.98
$m_H = 160$ GeV	/SUSYBBHToBB_M-160_7TeV-pythia6-tauola	6.22
$m_H = 180$ GeV	/SUSYBBHToBB_M-180_7TeV-pythia6-tauola	9.73
$m_H = 200$ GeV	/SUSYBBHToBB_M-200_7TeV-pythia6-tauola	14.80
$m_H = 250$ GeV	/SUSYBBHToBB_M-250_7TeV-pythia6-tauola	37.96
$m_H = 300$ GeV	/SUSYBBHToBB_M-300_7TeV-pythia6-tauola	87.52
$m_H = 350$ GeV	/SUSYBBHToBB_M-350_7TeV-pythia6-tauola	198.56

HLT

HLT paths (*L1 seed*)	run range	triggered events	$\int \mathcal{L} dt$ [pb^{-1}]
HLT_Mu12_CentralJet30_BtagIP *L1_SingleMu7*	163738-165633	3 027 717	180.9
HLT_Mu12_DiCentralJet30_BtagIP3D *L1_SingleMu10*	165970-166967	4 532 555	537.1
HLT_Mu12_DiCentralJet20_DiBtagIP3D1stTrack *L1_SingleMu10*	167039-173198	2 244 550	1108.6
HLT_Mu12_eta2p1_DiCentralJet20_DiBtagIP3D1stTrack *L1_Mu10_Eta2p1_DoubleJet_16_8*	173236-176469	1 237 147	652.2
HLT_Mu12_eta2p1_DiCentralJet20_DiBtagIP3D1stTrack* *L1_Mu10_Eta2p1_DoubleJet_16_8**	176545-180252	5 690 304	2326.8
All		16 732 273	4805.7

Trigger eff

HLT Path	signal efficiency [%]
HLT_Mu12_CentralJet30_BtagIP	3.64 ± 0.19
HLT_Mu12_DiCentralJet30_BtagIP3D	2.28 ± 0.11
HLT_Mu12_DiCentralJet20_DiBtagIP3D1stTrack	1.66 ± 0.07
HLT_Mu12_eta2p1_DiCentralJet20_DiBtagIP3D1stTrack	1.65 ± 0.06

Table: Signal efficiency for the different HLT paths. The reported signal efficiency is estimated only for the Higgs mass point $m_H = 120 GeV/c^2$ and it does not take into account the offline selection.

Physics Objects

- CMSSW 4_2_7 including JetMet suggested tags.
- AK5 ParticleFlow Jets, JEC applied:
  - L1FastJet, L2Relative, L3Absolute, L2L3Residual (only for Data)
  - Global Tag: `FT_R_42_V20A` and `START42_V17` for Data and MC
  - PU treatment: PF Charged Hadron Subtraction and Area Method;
  - Loose JetId selections;
- Jet b-tagging used is Combined Secondary Vertex (CSV);
- Standard Global Muon (no isolation requirements)

- JES and JER from POG (CERN-PH-2011/102 and update JetMET presentation 9/1/12);
- BTag efficiency studies on top samples (BTV-12-001);
- Muon (non isolated) efficiency on J/ψ MUO-10-004;

Data reduction

Cut	Mu12 CentralJet30 BTagIP	Mu12 DiCentralJet30 BTagIP3D	Mu12 DiCentralJet20 DiBTagIP3D1stTrack	Mu12_eta2p1 DiCentralJet20 DiBTagIP3D1stTrack	Mu12_eta2p1 DiCentralJet20_NewJEC DiBTagIP3D1stTrack	All
All	3027717	4532555	2244550	1237147	5690304	16732273
$p_T^{\mu} > 15\ GeV$	1757902	2678935	1337394	742231	3222677	9739139
$\# jets >= 3$	665962	1245655	639616	404082	1556012	4511327
$\Delta R_{ij} >= 1$	513981	957884	498996	315284	1219439	3505584
$CSV(1^{st} - jet) > 0.8$	242982	492734	297838	184075	714506	1932135
$CSV(2^{nd} - jet) > 0.8$	52345	112428	162029	99175	387708	813685
μ in 1^{st} or 2^{nd} jet	50708	108551	156147	95760	374774	785940
$CSV(3^{rd} - jet) > 0.7$	3245	7323	12796	7623	29208	60195
$\int \mathcal{L} dt\ [pb^{-1}]$	180.9	537.1	1108.6	652.2	2326.816	4805.7

Table: Data reduction after each selection cut for the various trigger paths

Signal reduction

Cut	M_H [GeV] 90	100	120	130	140	160	180	200
All	3181487	2282039	1225179	942164	664435	425194	271531	178458
$p_T^{\mu} > 15$ GeV	79166	71272	53760	47703	37522	29513	21972	16306
$\#jets >= 3$	13416	13012	11321	10649	9028	8009	6546	5290
$\Delta R_{ij} >= 1$	11709	11423	9796	9161	7689	6729	5386	4267
$CSV(1^{st} - jet) > 0.8$	7452	7339	6416	5970	5133	4440	3545	2834
$CSV(2^{nd} - jet) > 0.8$	4202	4078	3752	3405	3003	2662	2172	1747
μ in 1^{st} or 2^{nd} jet	3617	3508	3222	2937	2611	2321	1873	1509
$CSV(3^{rd} - jet) > 0.7$	1338	1324	1305	1160	1079	953	744	591
ϵ [%]	0.042	0.058	0.107	0.123	0.162	0.224	0.274	0.331

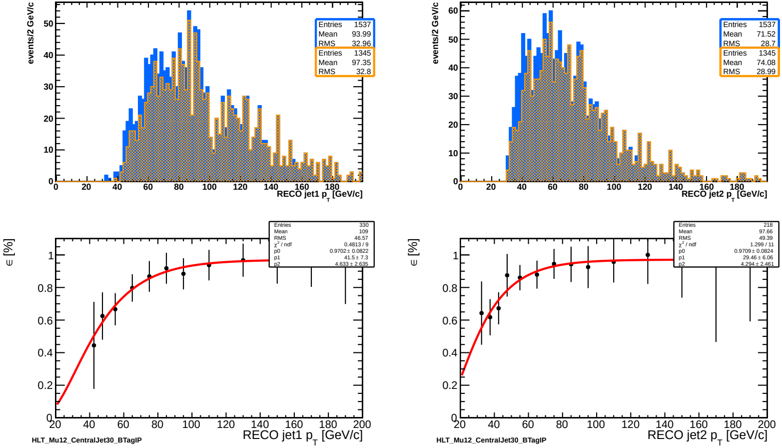
Table: Events reduction for selection cuts for SUSY simulated signal samples, normalized to a cross section for $\tan\beta = 30$, for mass point in the low mass range $M_H < 200$ GeV. The trigger efficiency is included only starting from the cut $\#jets >= 3$ by applying the data driven turn-on curves.

Signal reduction

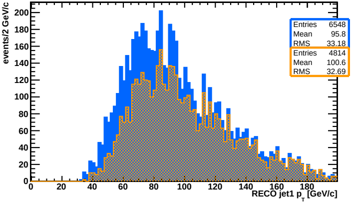
Cut	M_H [GeV] 250	300	350
All	69624	29935	13310
$p_T^\mu > 15\ GeV$	8040	4014	1999
$\#jets >= 3$	3012	1686	901
$\Delta R_{ij} >= 1$	2381	1303	685
$CSV(1^{st} - jet) > 0.8$	1584	850	441
$CSV(2^{nd} - jet) > 0.8$	986	531	271
μ in 1^{st} or 2^{nd} jet	860	465	239
$CSV(3^{rd} - jet) > 0.7$	340	181	92
ϵ [%]	0.488	0.605	0.691

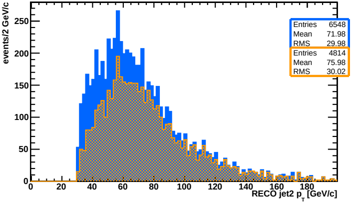
Table: Events reduction for selection cuts for SUSY simulated signal samples, normalized to a cross section for $\tan\beta = 30$, for mass point in the high mass range $M_H > 200\ GeV$. The trigger efficiency is included only starting from the cut $\#jets >= 3$ by applying the data driven turn-on curves.

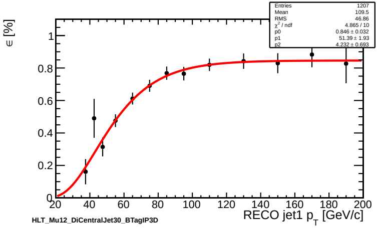
HLT_Mu12_CentralJet30_BTagIP

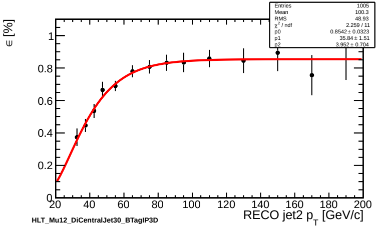


HLT_Mu12_DiCentralJet30_BTagIP3D

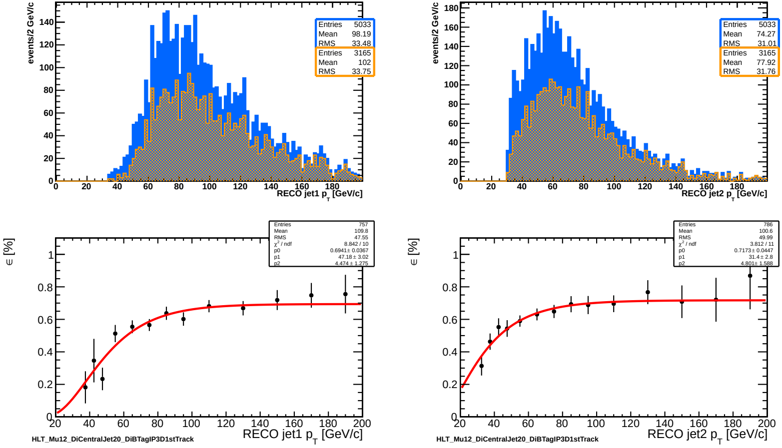




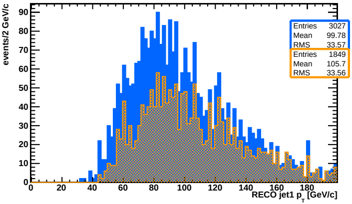


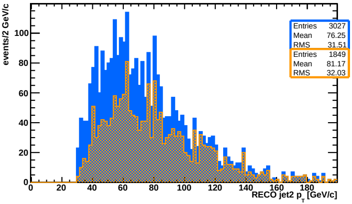


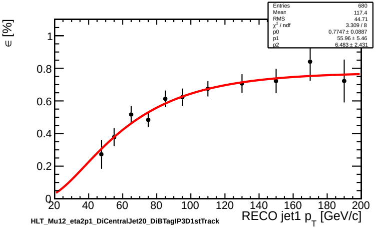
HLT_Mu12_DiCentralJet20_DiBTagIP3D1stTrack

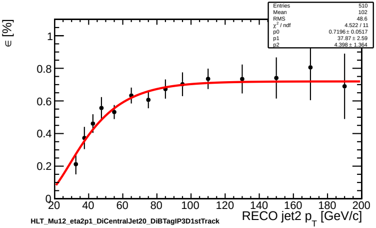


HLT_Mu12_eta2p1_DiCentralJet20_DiBTagIP3D1stTrack

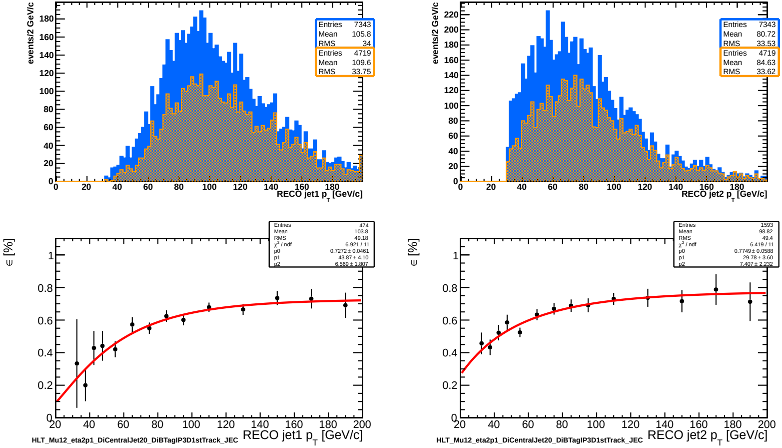








HLT_Mu12_eta2p1_DiCentralJet20_DiBTagIP3D1stTrack

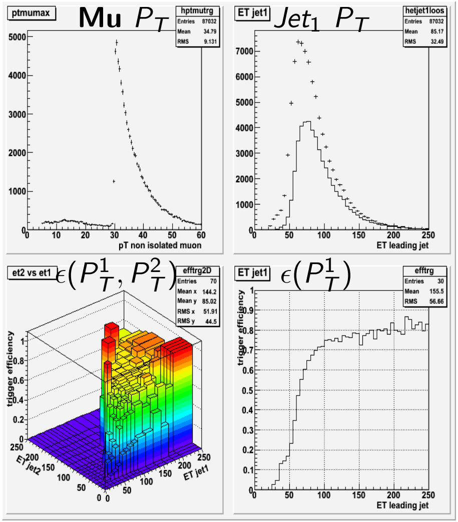


Trigger Efficiency vs Analysis

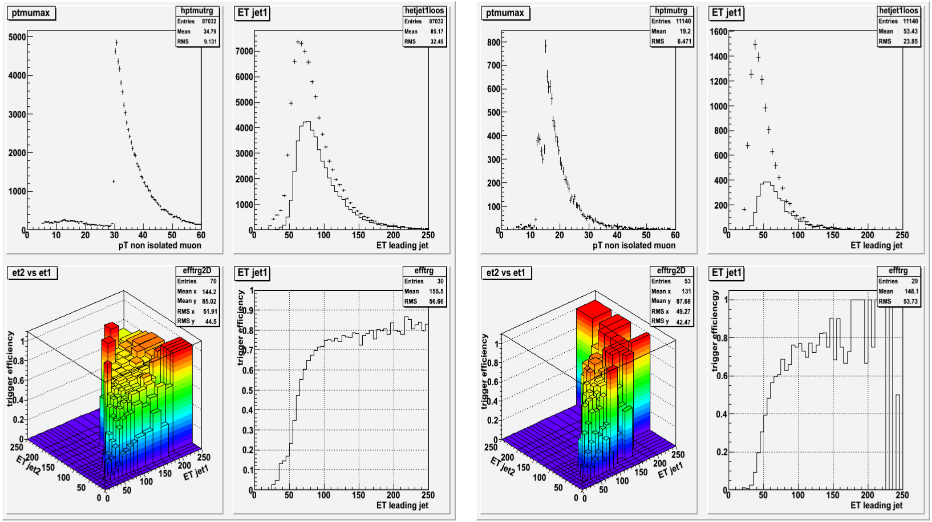
- Use **SingleMuon PD**, select all events passing a single muon path.
- Apply preselection (2 bjets)
- Build Turn on curves vs first and second B-jets Pt:

$$\epsilon = \frac{\text{Hbb path \& presel \& SingleMuHLT}}{\text{presel \& SingleMuHLT}}$$

- Here for `HLT_Mu12_DiCentralJet30_BtagIP3D` and `SingleMu30`
- Turn-on stable wrt SingleMu threshold



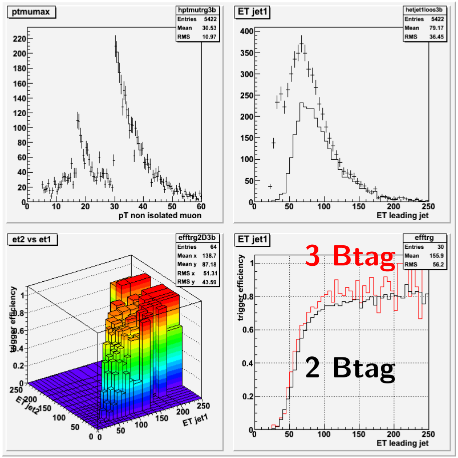
Trigger Efficiency (I)



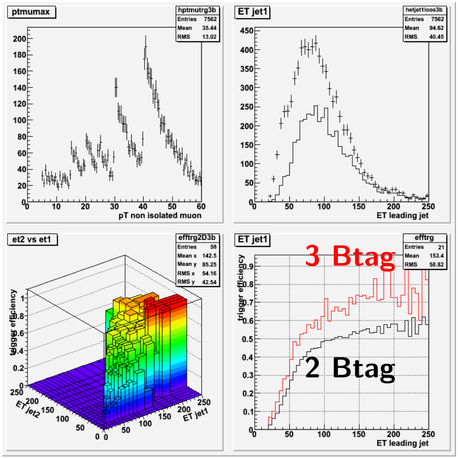
Turn-on stable for different SingleMu threshold (left Mu30, right Mu12 &

Trigger Efficiency (II) 2 btags vs 3 btags

HLT_Mu12_DiCentralJet30_BtagIP3D



HLT_Mu12_DiCentralJet20_DiBtagIP3D1stTrack



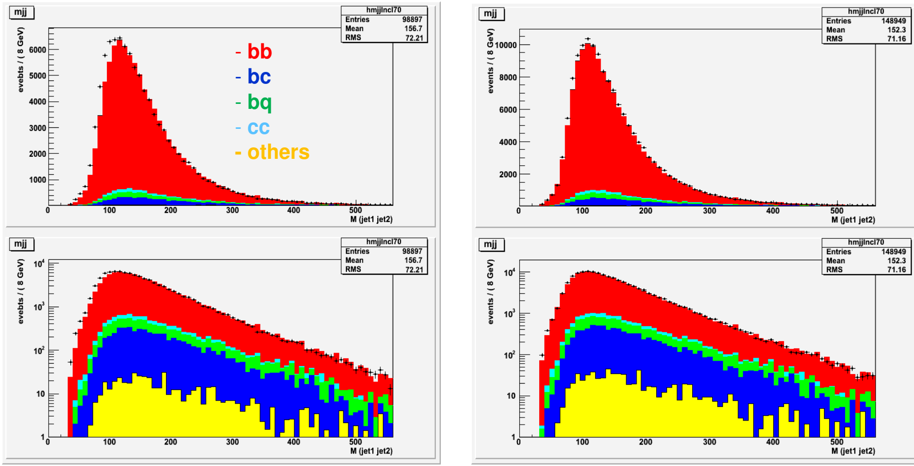
Statistics bit low but still affordable

Mass spectra, trigger corrected

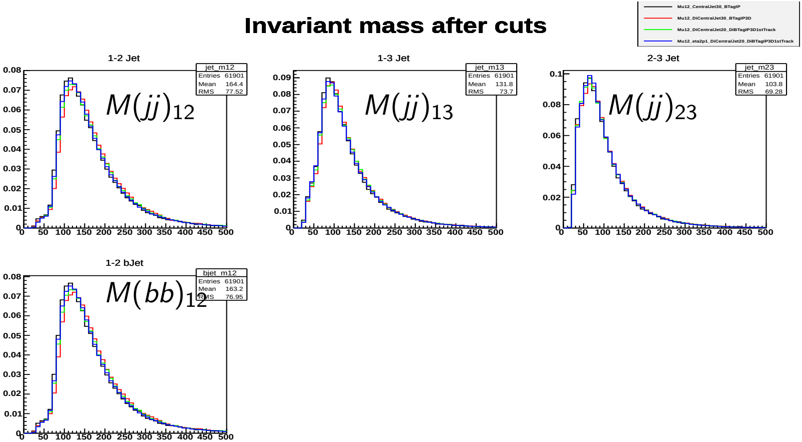
HLTMu12_DicentralJet30_BtagIP3D L = 525 pb-1

2 btags

HLTMu12_DicentralJet20_DiBtagIP3D1stTk L = 1002 pb-1

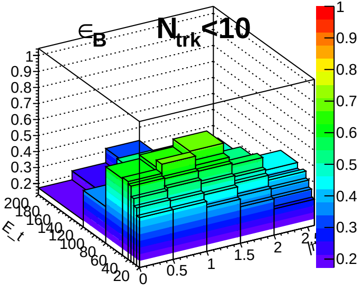


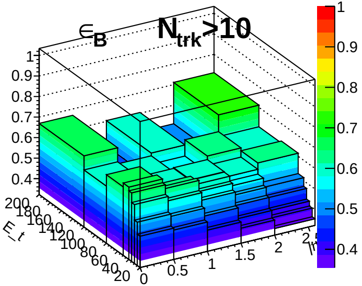
M_{jj} and M_{bb} for different HLT paths



Applying pre-selections (2 b-tag) only: no bias in M_{jj} nor M_{bb}

ϵ_b for bbj vs $|\eta|$, E_t vs N_{trk}

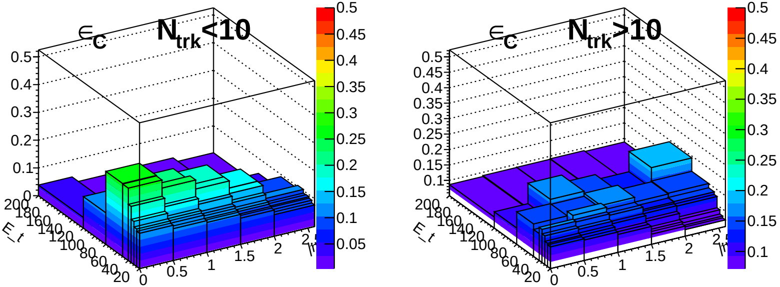




Left to Right:

ϵ_B All, $N_{trk} < 10$, $N_{Trk} \geq 10$

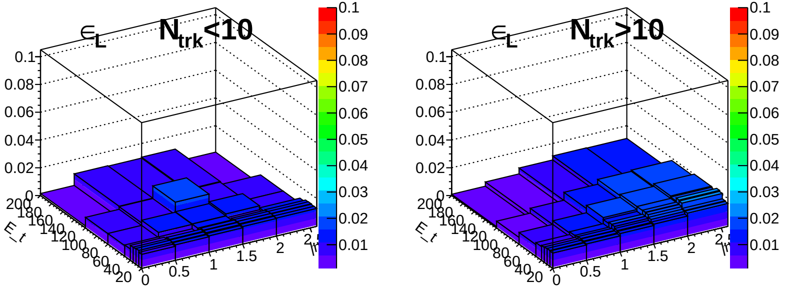
ϵ_c for bbj vs $|\eta|$, E_t vs N_{trk}



Left to Right:

ϵ_C All, $N_{trk} < 10$, $N_{Trk} \geq 10$

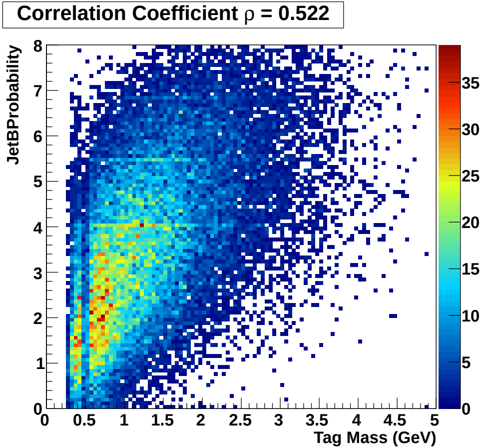
ϵ_{light} for bbj vs $|\eta|$, E_t vs N_{trk}



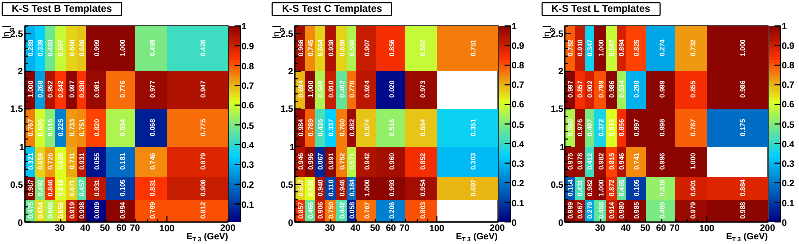
Left to Right:

ϵ_{Light} All, $N_{trk} < 10$, $N_{Trk} \geq 10$

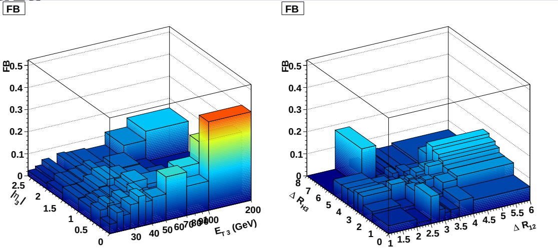
Mass@Vertex and JetBProbabiliy correlation



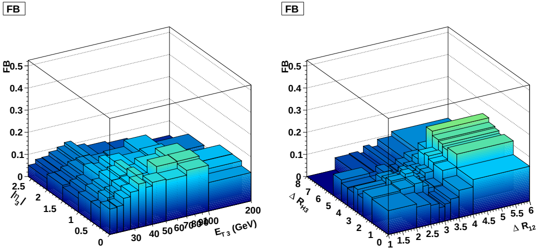
Template jjj vs bbj



Fb in Data



(a) Single Btag triggered sample



$F_{b,c}$ parametrization

$$F_{B,C}\left(E_T^{(j_3)}, \left|\eta^{(j_3)}\right|\right) \times F_{B,C}\left(\Delta R_{H,j_3}, |\Delta R_{j_1,j_2}|\right)$$

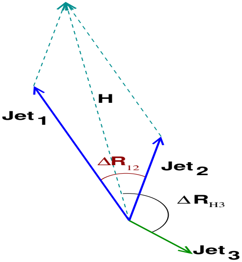
assuming no correlation.

One factor for the third jet features, one for the event topologies.

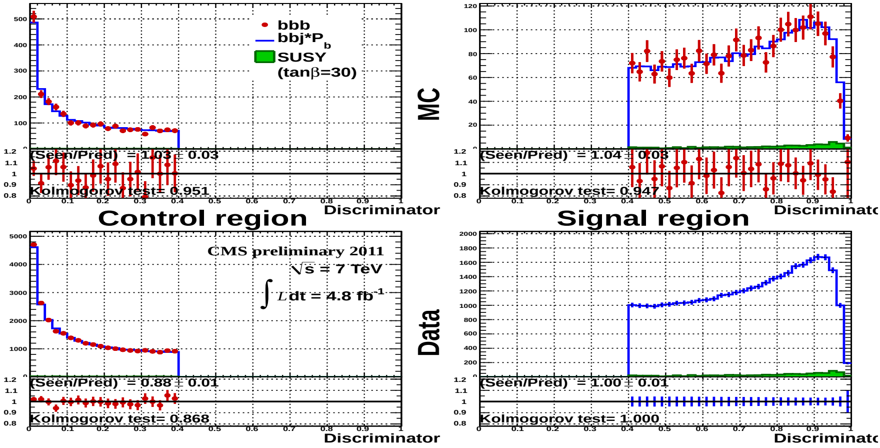
Use $F_{B,C}(\Delta R_{H,j_3}, |\Delta R_{j_1,j_2}|)$ only for shape:

$F_{B,C}$ average, weighted to *bbj* distribution, is normalized to unity.

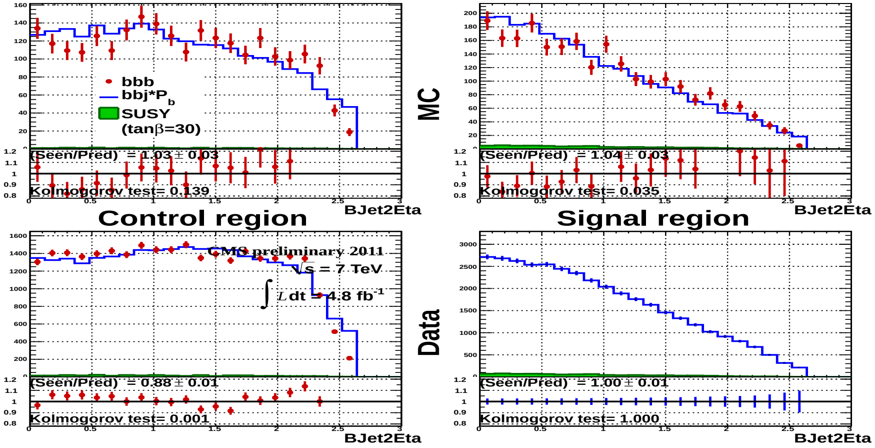
$$\int_{C\ reg.} \frac{dN}{d\Delta R_{12} d\Delta R_{H,j3}} \cdot F_{B,C}\left(\Delta R_{H,j3}, \Delta R_{12}\right) d\Delta R_{12} d\Delta R_{H,j3} = \int_{C\ reg.} \frac{dN}{d\Delta R_{12} d\Delta R_{H,j3}} d\Delta R_{12} d\Delta R_{H,j3}$$



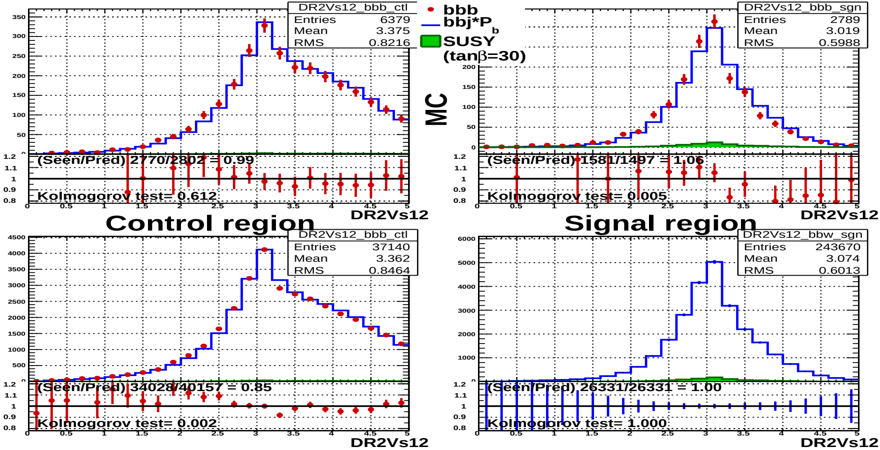
Prediction vs *bbb* in MC and Data



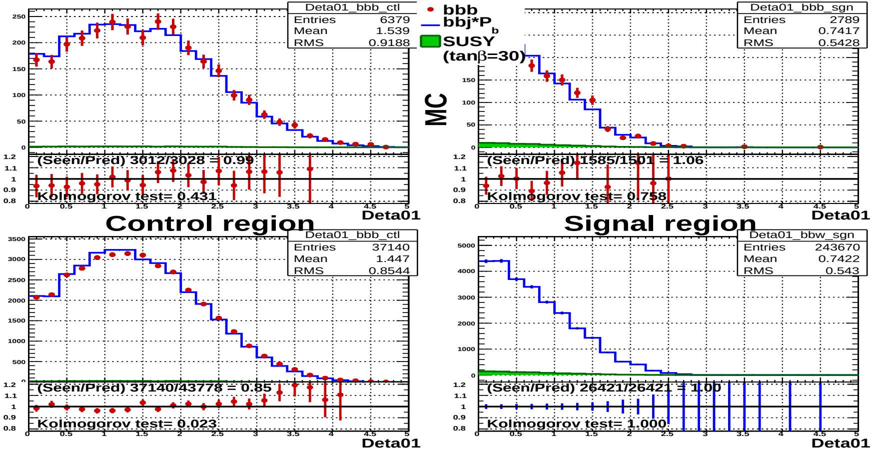
Prediction vs *bbb* in MC and Data



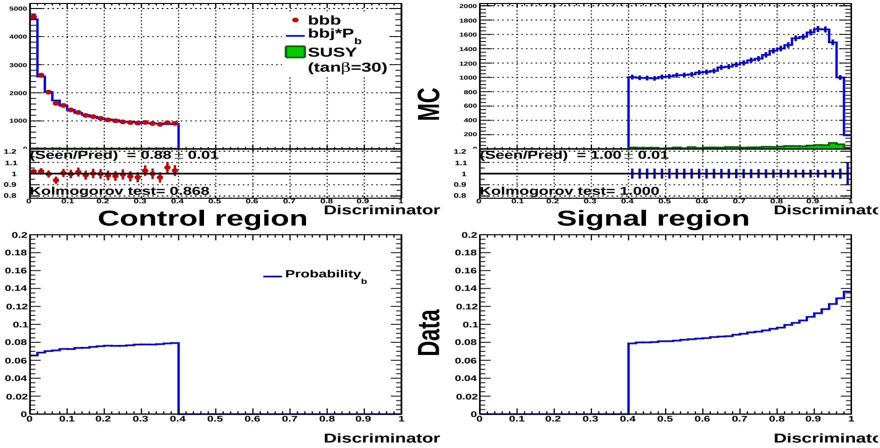
Prediction vs *bbb* in MC and Data



Prediction vs *bbb* in MC and Data

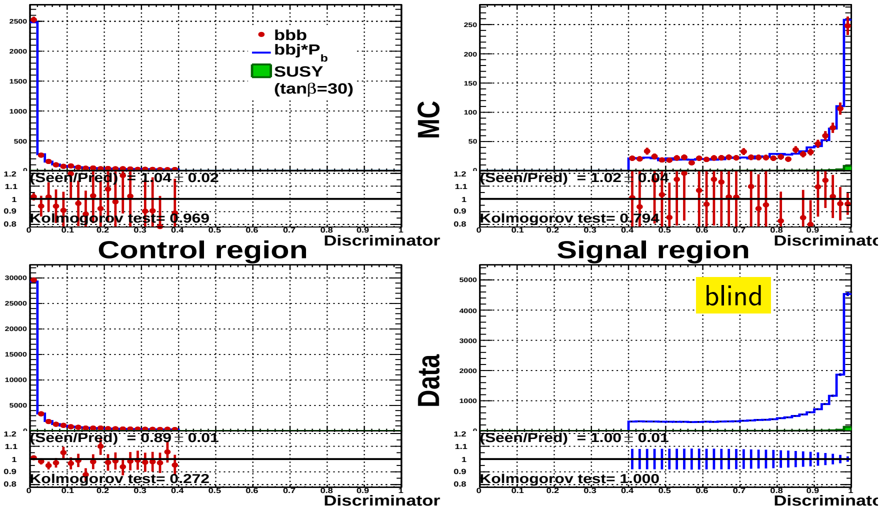


Prediction vs *bbb* and Data



Discriminator prediction vs *bbb* in MC and Data

in control and signal region: High Mass ($M_H > 200$) susy $M_H = 250\ GeV$

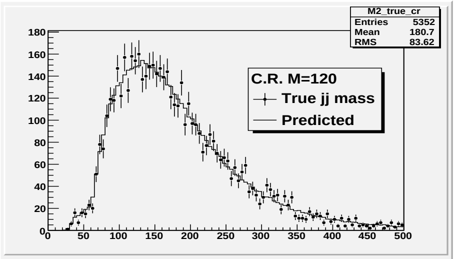


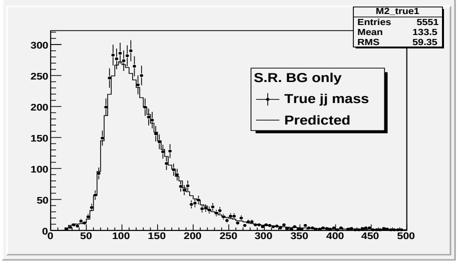
Variable used in HB

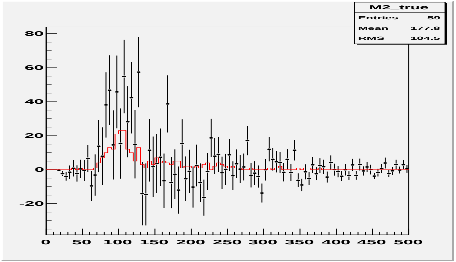
E_{T1}	1$^{\rm st}$ jet transverse energy
η_1	1$^{\rm st}$ jet pseudorapidity
E_{T2}	2$^{\rm nd}$ jet transverse energy
η_2	2$^{\rm nd}$ jet pseudorapidity
$n_{\rm tk2}$	2$^{\rm nd}$ jet track multiplicity
E_{T3}	3$^{\rm rd}$ jet transverse energy
η_3	3$^{\rm rd}$ jet pseudorapidity
$n_{\rm tk3}$	3$^{\rm nd}$ jet track multiplicity
$\Delta\varphi_{12}$	1$^{\rm st}$ and 2$^{\rm nd}$ jet azimut difference
ΔR_{23}	2$^{\rm nd}$ and 3$^{\rm rd}$ jet R distance
M_{12}	1$^{\rm st}$ and 2$^{\rm nd}$ jet invariant mass
p_{T12}	1$^{\rm st}$ and 2$^{\rm nd}$ jet combined transverse momentum
p_{T23}	2$^{\rm nd}$ and 3$^{\rm rd}$ jet combined transverse momentum
p_{T123}	1$^{\rm st}$, 2$^{\rm nd}$ and 3$^{\rm rd}$ jet combined transverse momentum

Table: List of variables used to build the "distance" as defined in eq.**??**

Hyper Ball: results on QCD MC







Example of signal injection and extraction $M_H = 120\ GeV$

Limit and systematics

Results using combine tool from Higgs Group

for $M_H = 120$

expected limit with all syst

Expected 50.0%: $r < 256.2458\ pb$

expected limit with all syst BUT bkgNorm

Expected 50.0%: $r < 81.6096\ pb$

the bkgNorm systematics is just 4.5%: such a huge leap is weird!