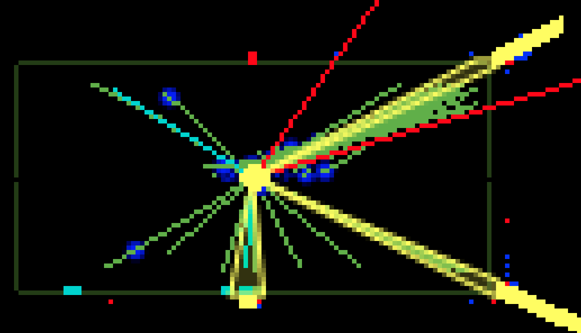
Observation of the Z+b final state in pp collisions at 7 TeV with the CMS experiment at LHC



Ludivine Ceard, Jerome de Favereau, Christophe Delaere,
Tristan du Pree (CP3, UCLouvain)
20th April 2011
CP3 Lunch Seminar

Synopsis

- INTRODUCTION AND MOTIVATIONS
- ANALYSIS SETTINGS
  - Data Taking Conditions
  - MC Samples
  - Effect of Flavor Scheme
- EVENT SELECTION
  - Electrons Selections
  - Muons Selection
  - Z Candidates Selection
  - Jets
  - B tagging and SSV
  - MET
- RESULTS
  - (Z+b)/(Z+j)
  - Purity from Data
- SIGNAL PROPERTIES
  - Z+b
  - Zb(b)
- CROSS CHECKS
  - MC Sheme Effect
  - ttbar Rejection with MEM
- FIRST 2011 DATA
- CONCLUSION

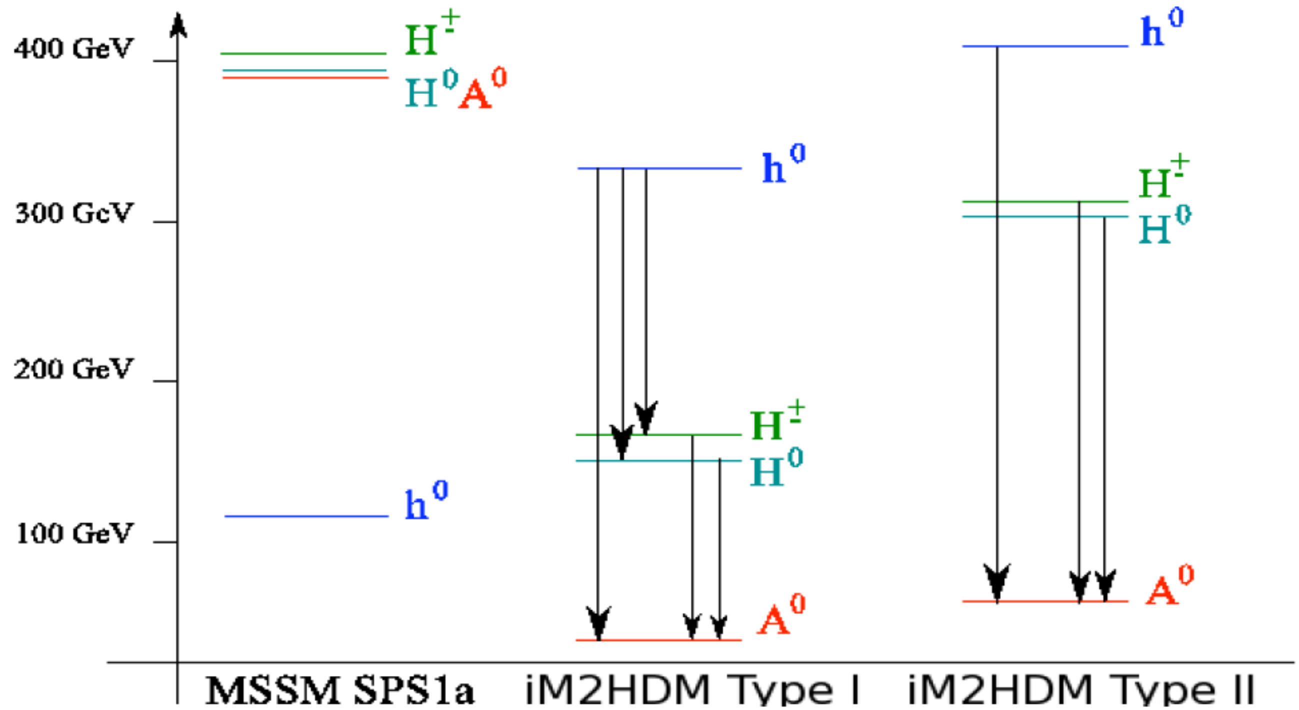
Introduction et Motivations

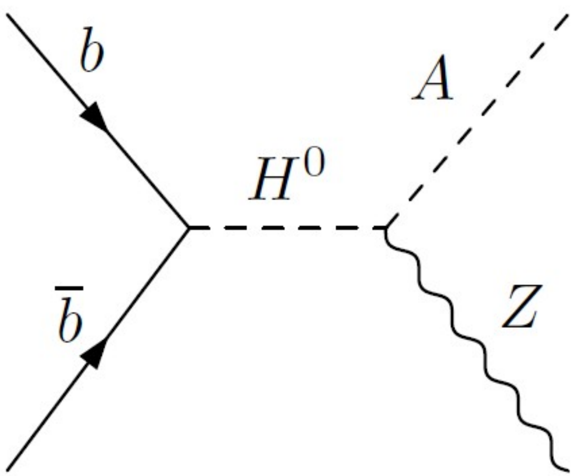
- Measure σ_{Zb} et σ_{Zbb} to confirm/constrain theoretical NLO σ
- bb+ φ benchmark in MSSM
- Cross section calculation for the 4 and 5-flavor schemes
- Background to Higgs searches and new physics
- Group interest
  → iM2HD = inverse mass Minimum 2 Higgs Doublets Model

iM2HDM

2 doublets -> 5 Higgs

Allows decays that couldn't take place in SUSY





Favored Channel :

A -> bb
Z -> l+l-

Theory

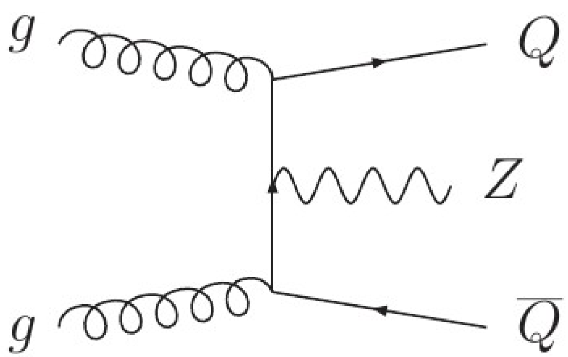
Calculations currently derived in 2 ways :

Fixed-flavour scheme

Dittmaier, Kramer, Spira, Dawson, Jackson, Reina, Wackeroth

Explicit gluon splitting -> divergences if massless b.

massive b, g -> bb) 1 or 2 b observed

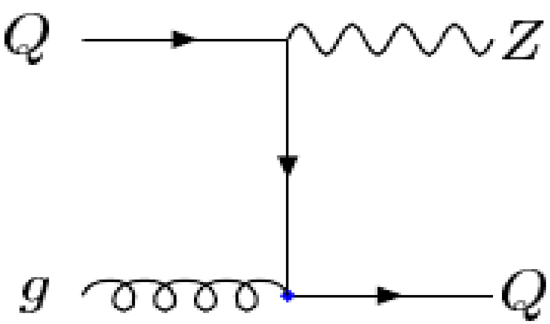


Variable-flavour scheme

Campbell, Ellis, Maltoni, Willenbrock

g -> bb inside b-PDF -> all orders = no divergences.

in calculations, b is massless.
second b added during parton shower and hadronisation by Pythia



Should agree at NLO

Analysis Settings

Data taking Conditions

- Full data sample from 2010
- Using lumimask which correspond to 36.1 pb-1

- Datasets are skimmed on Dileptons -> 2 electrons or 2 muons with pT > 10 GeV
  selection cuts for quality of data taking

- Triggers = conditions have changed several times within 2010
  -> using a OR of all triggers
  -> tightest being HLT_Ele22_SW_TighterCaloIdIsol_L1R_v2 and HLT Mu15 v1
  -> our selection cuts are tighter (pT> 20 and 25 GeV, slide n°11/12)
  -> triggers are all Unprescale Single Leptons (will change for 2011)
  -> 100 % efficiency

- CMSSW_3_9_9 + packages

Full 2010 pp collisions Reprocessed 22Dec Skimmed DiLeptons datasets :

Dataset	Number of Events
/EG/Run2010A-DiLeptonEle-Dec22Skim_v2/RECO	1019114
/Electron/Run2010B-DiLeptonEle-Dec22Skim_v2/RECO	3569988
/Mu/Run2010A-DiLeptonMu-Dec22Skim_v2/RECO	376175
/Mu/Run2010B-DiLeptonMu-Dec22Skim_v2/RECO	4443236

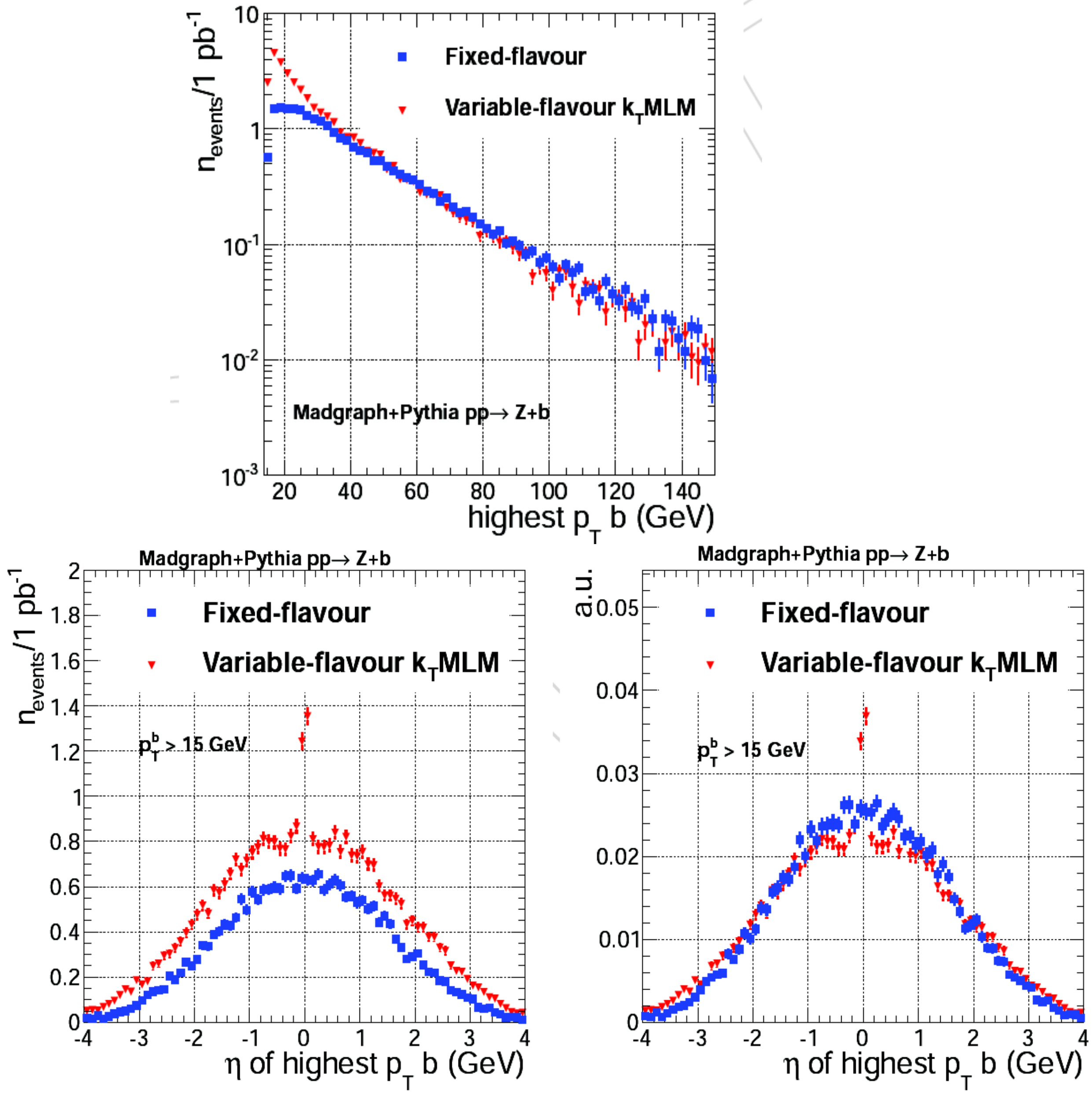
MC samples

MonteCarlo samples for signal and backgrounds, (normalized to NNLO or NLO), tune Z2

Generator	Process	Kinematic cuts (in GeV, $c=1$)	σ (pb)		Events	Weight for 35.9 pb^{-1}
MADGRAPH	DYJet	$m_{\ell\ell} > 50$	3048	NNLO	5.2M	0.0208
MADGRAPH	Z+c	$m_{\ell\ell} > 40, p_T^c > 15$	40.8	NLO	40k	0.0365
MADGRAPH	Z+b	$m_{\ell\ell} > 40, p_T^b > 15$	25.8	NLO	26k	0.0355
MADGRAPH	$t\bar{t}$	no cut	165	NLO	1.3M	0.0459

- For Z+b and Z+c components: specific fixed-flavour Madgraph samples.
- For Z+l components: Madgraph state-of-the-art sample for inclusive jets, variable-flavour, with veto on events with b/c at generator level.
- Alternative: Z+j inclusif: same inclusive sample withoutVeto = Z+j.
- Comparison versus data shown on slide n°33

Effect of flavor scheme



Event Selection

Electrons Selection

Selection variables	Tight Electron	Matched Electron
Working Point	WP85 (incl. fiducial cuts)	
p_T	$p_T > 25$ GeV	
$\|\eta\|$	$\|\eta\| < 2.5$	
d0	$d0 < 0.02$ cm	
Trigger Matching	-	$\Delta R < 0.3$ and $\Delta p_T / p_T < 0.5$

WP85 = Working Point efficiency 85, Electron ID based on Simple cuts

We require trigger matching for further trigger efficiency studies for the future (Tag an Probe)

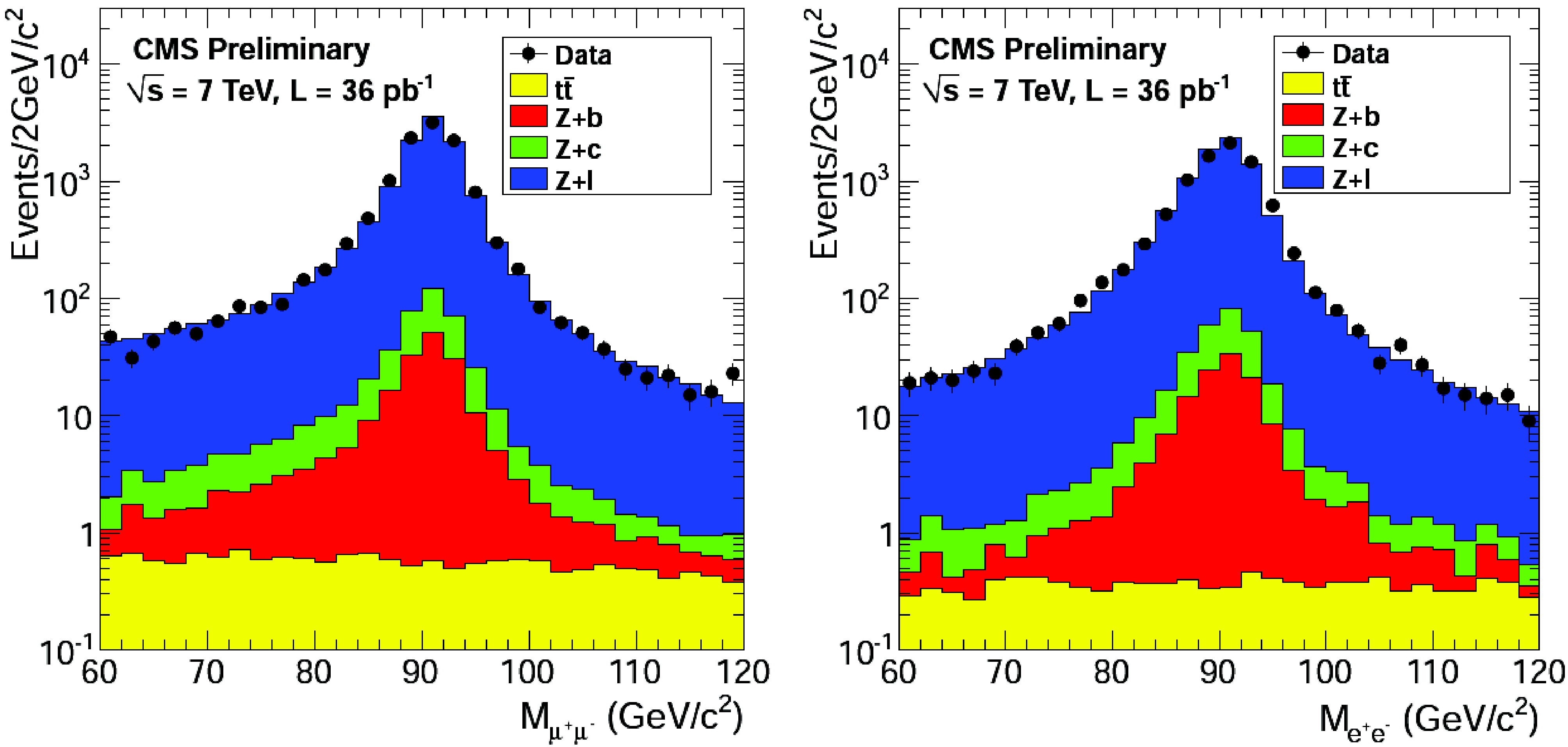
Muons Selection

Selection variables	Tight Muon	Matched Muon
Type	isGlobal and isTracker	
Number_TRK_Hits + Number_PIX_Hits	> 10	
(Sum_pT_TRK + Sum_eT_ECAL + Sum_eT_HCAL)/p_T	< 0.15	
p_T	> 20 GeV	
$\|\eta\|$	< 2.1	
Number_PIX_Hits	> 0	
Number_Muon_Hits	> 0	
Segments Matched	> 1 muon station	
d0	< 0.02 cm	
$\|\chi^2\|$	< 10	
Trigger Matching	-	$\Delta R < 0.3$ and $\Delta p_T / p_T < 0.5$

We again require trigger matching for further trigger efficiency studies for the future

Z Candidate Selection

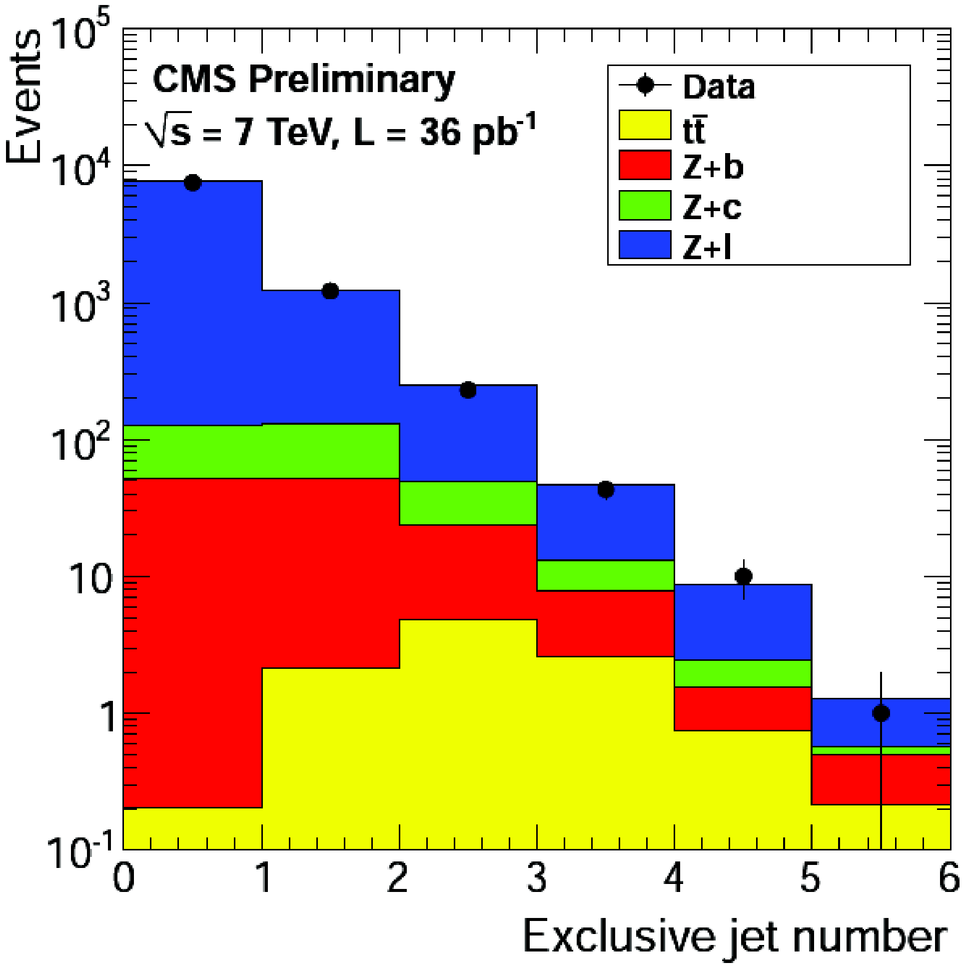
- Require 1 tight and 1 matched opposite charge electrons or muons
- Mass range [60-120]



JETS

- PF Jets antikT algo 0.5
- JEC for Spring 2010

- pT > 25 Gev and |η|< 2.1
- Jet ID loose
- Overlapping avoided with lepton from Z with ΔR >0.5 (size of jet)



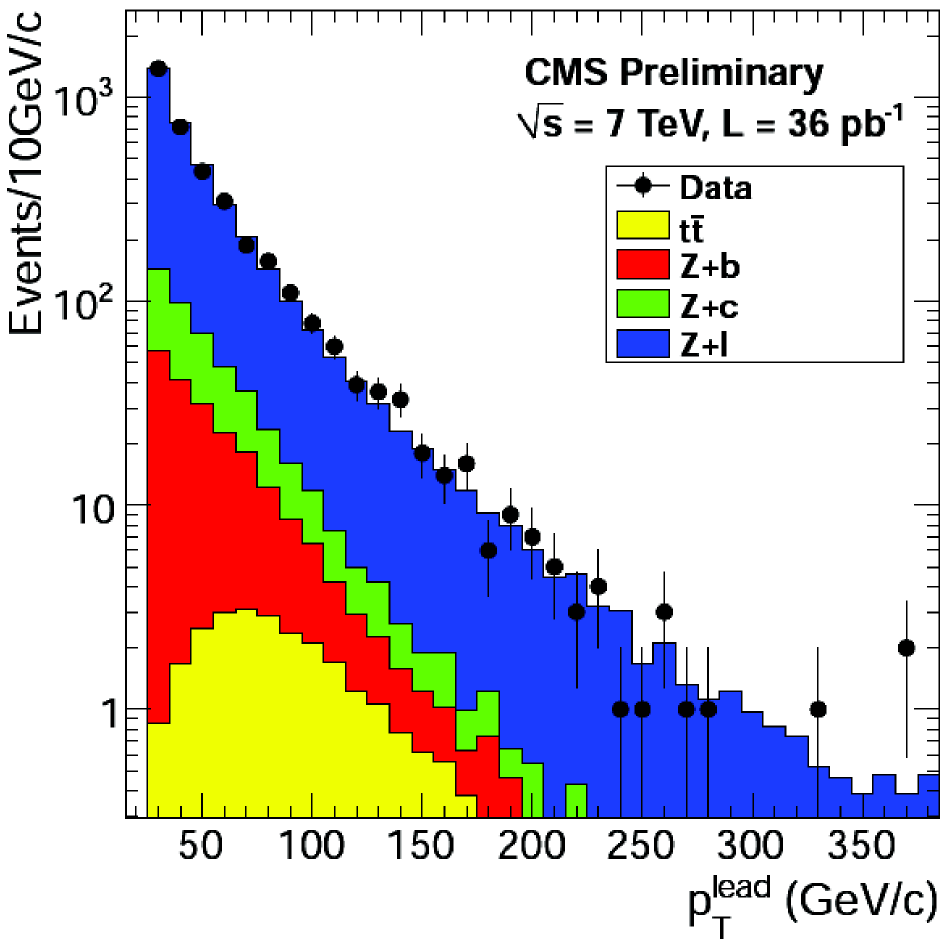
Number of jets per event containing a Z

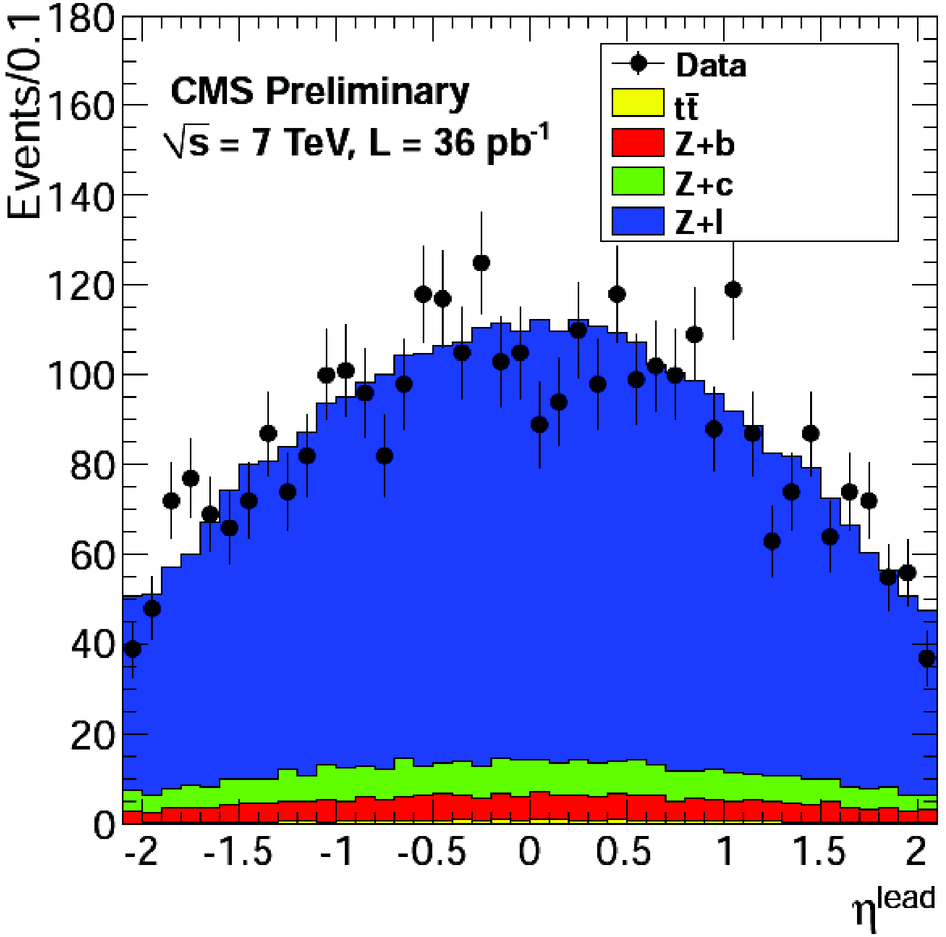
Data in agreement with MC

Relative ratio Znj/Z(n+1)j~1/5
-> in agreement with previous studies on jets + V

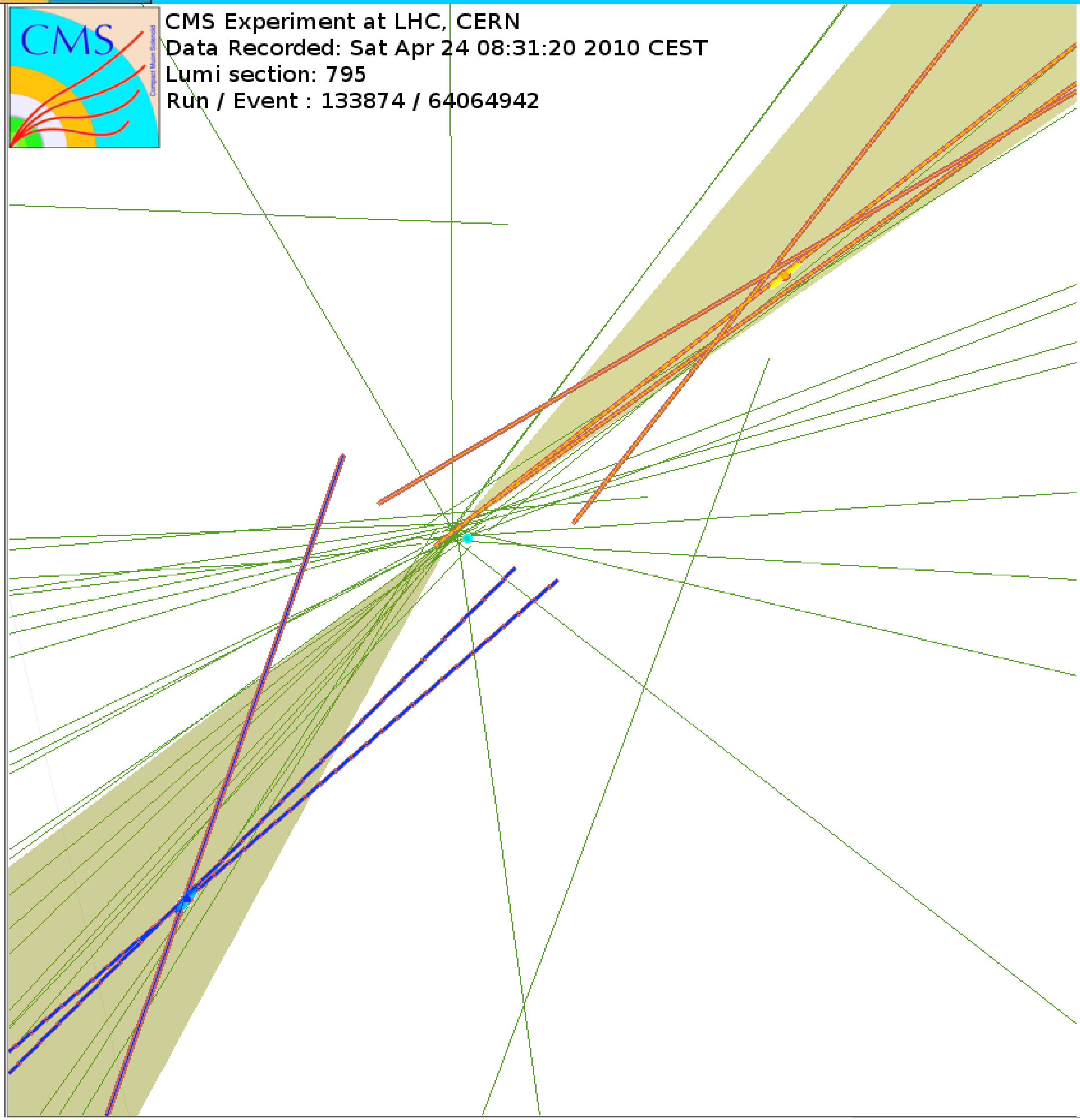
Z+j signal properties

pT and eta of leading jet after Z + jet Selection step





B Tagging



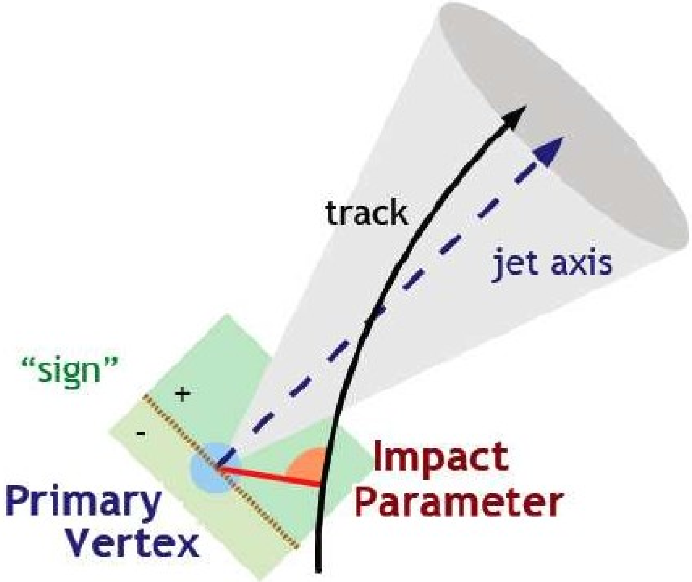
Bbbar event

- B hadron longer time of flight
- Reconstruction of a second vertex with dedicated algorithm
  - -> Distance from primary vertex = d0
  - -> Masse
- Displaced tracks

B Tagging

- Track-counting (TC): tracks ordered by IP
  High-Eff (HE) = 2nd track,
  High-Pur (HP) = 3rd track.

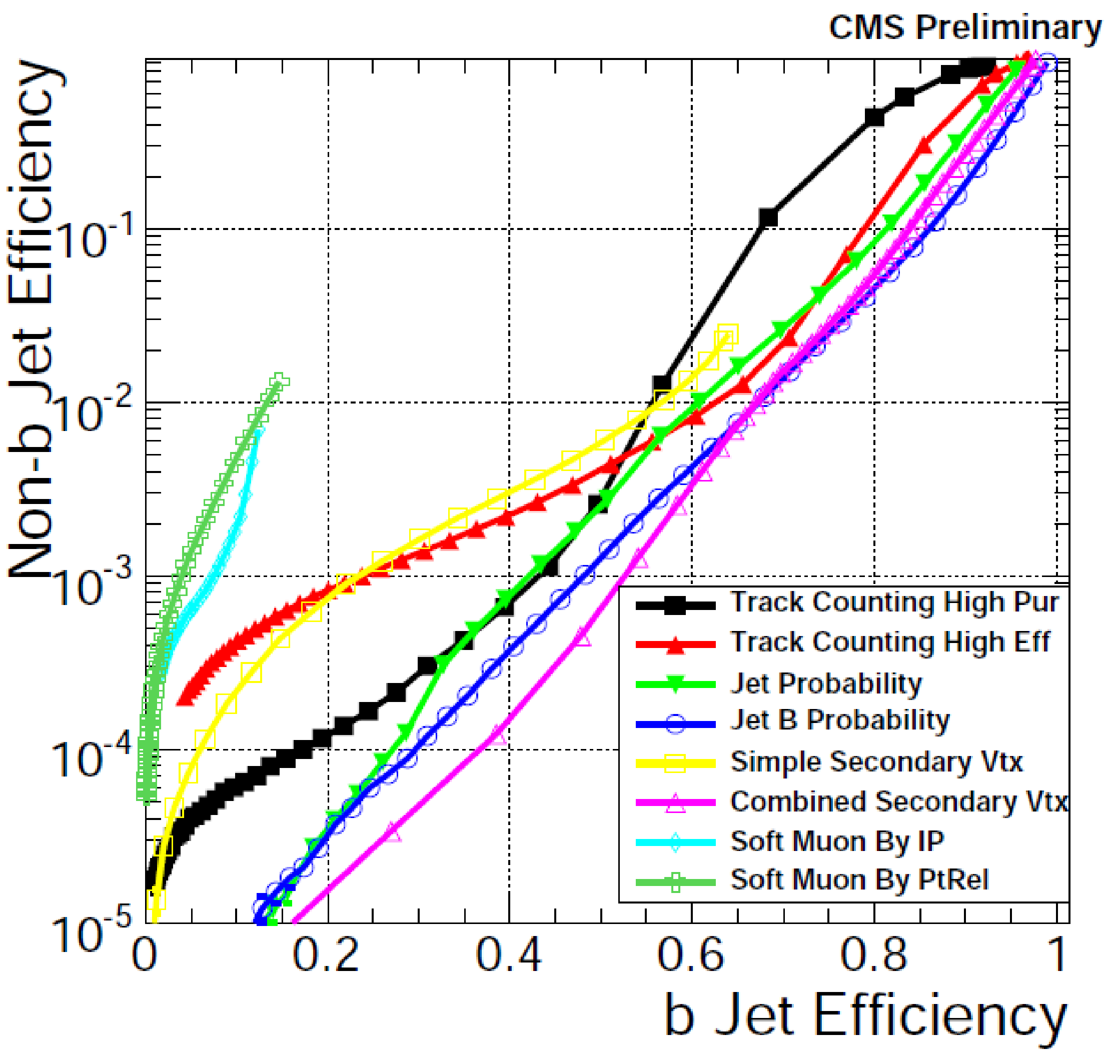
- Simple Secondary Vertex (SSV): at least
  2 (High-Eff) or
  3 (High-Pur) tracks in vertex fit.



Working point	Requirement	Discriminant	Cut
SSVHEM	One secondary vertex with ≥ 2 tracks	$Log(1+\frac{d_0}{\sigma_0})$	1.74
SSVHPT	One secondary vertex with ≥ 3 tracks		2.0

$d0/\sigma0$ = flight distance significance

B Tagging

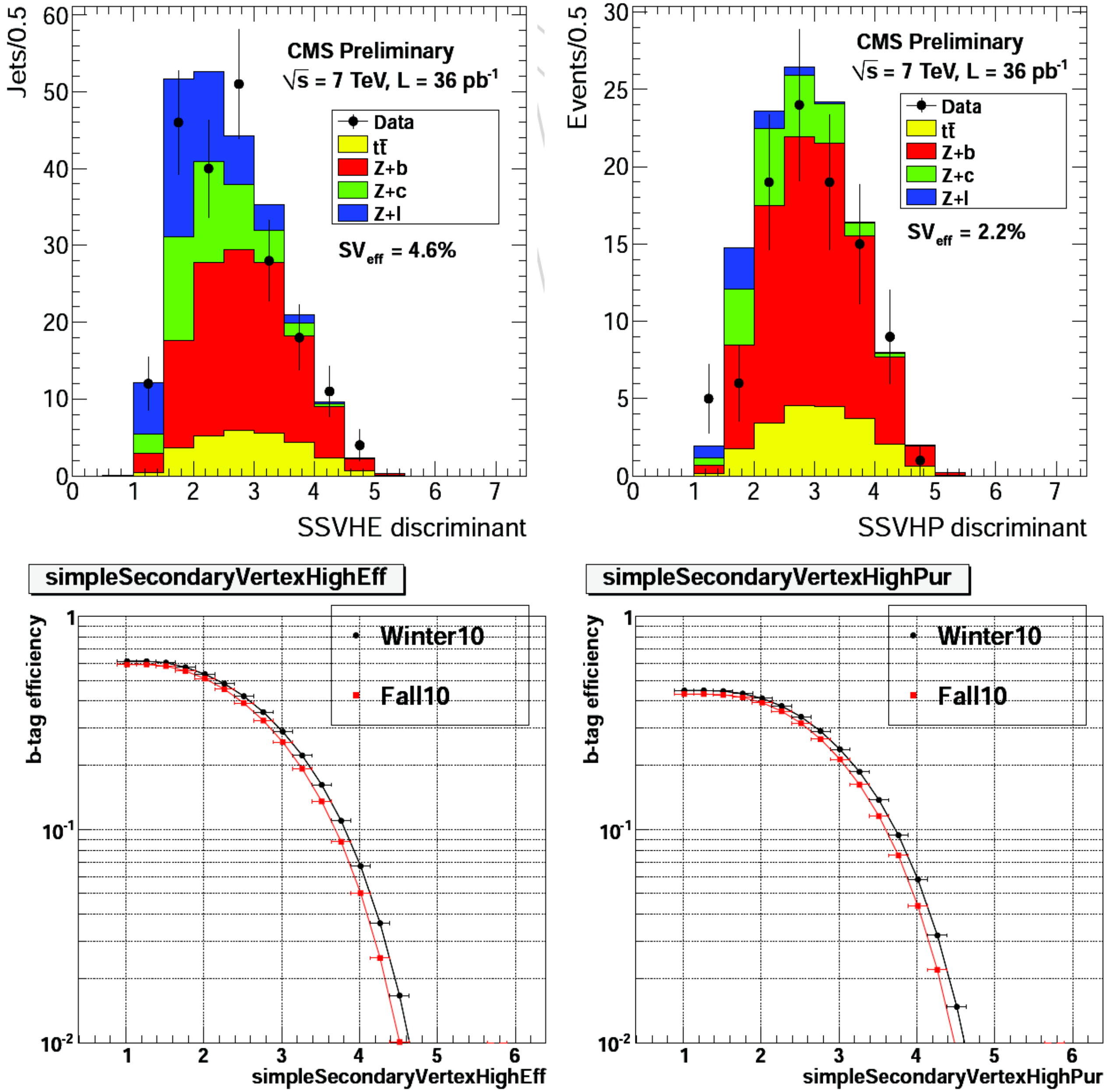


- Only two approved algorithms : Track counting and SSV
- SSV similar than TCHE for the same b jet efficiency
- SSV less good than TCHP for high purity

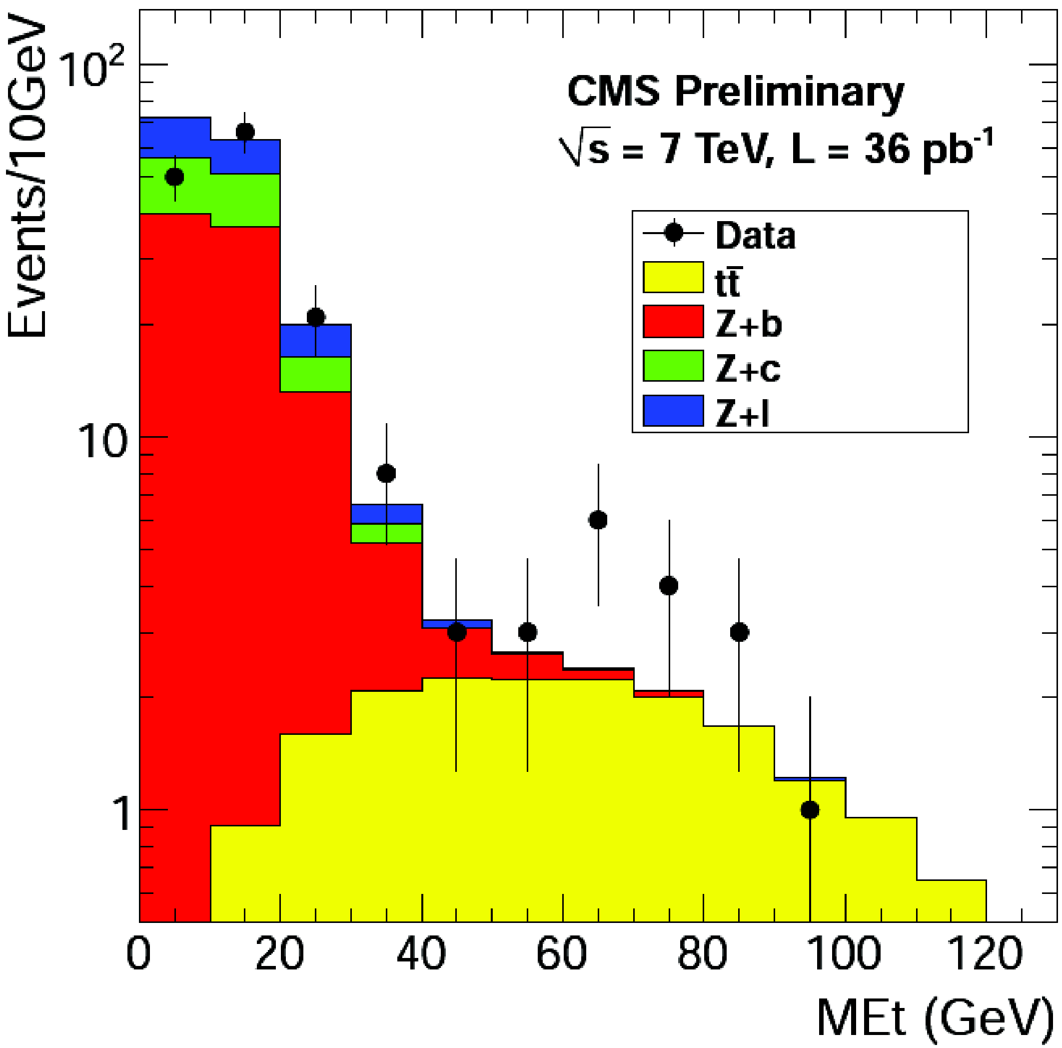
But SSV gives the vertex reconstruction and information

MC 2009

SSV b tagging



MET



From Z+b and tt MC distributions

→ MET cut at 40 GeV to reject tt background

Z+jet in selection

Results

Relative Z+b / Z+jet ratio

Z + B Yield

Selection	2010 data	MC	$t\bar{t}$	$Z+l$	$Z+c$	$Z+b$
$Z(e^+e^-)$	8982 ± 95	9262 ± 14	10.7 ± 0.2	8940 ± 14	184 ± 3	127 ± 2
$Z(e^+e^-)j$	1490 ± 39	1521 ± 6	10.5 ± 0.2	1327 ± 5	108 ± 2	75.7 ± 1.6
$Z(e^+e^-)b$ [HE]	61 ± 8	71.8 ± 1.5	7.8 ± 0.2	13.5 ± 0.5	14.5 ± 0.7	36.0 ± 1.1
$Z(e^+e^-)b$ [HE+MET]	54 ± 7	65.3 ± 1.4	2.0 ± 0.1	13.4 ± 0.5	14.5 ± 0.7	35.5 ± 1.1
$Z(e^+e^-)b$ [HP+MET]	29 ± 5	32.8 ± 1.1	1.6 ± 0.1	0.8 ± 0.1	5.3 ± 0.4	25.1 ± 0.9
$Z(e^+e^-)bb$ [2*HP+MET]	1 ± 1	2.0 ± 0.2	0.4 ± 0.04	0.0 ± 0.06	0.04 ± 0.04	1.5 ± 0.2
$Z(\mu^+\mu^-)$	11993 ± 110	12088 ± 16	16.4 ± 0.3	11634 ± 16	254 ± 3	184 ± 3
$Z(\mu^+\mu^-)j$	2141 ± 46	2154 ± 7	16.0 ± 0.3	1872 ± 6	153 ± 2	113 ± 2
$Z(\mu^+\mu^-)b$ [HE]	104 ± 10	106 ± 2	11.9 ± 0.2	18.6 ± 0.6	20.3 ± 0.9	55.2 ± 1.4
$Z(\mu^+\mu^-)b$ [HE+MET]	91 ± 10	96 ± 2	3.0 ± 0.1	18.5 ± 0.6	20.3 ± 0.9	54.4 ± 1.4
$Z(\mu^+\mu^-)b$ [HP+MET]	36 ± 6	48.3 ± 1.3	2.4 ± 0.1	1.3 ± 0.2	7.2 ± 0.5	37.5 ± 1.2
$Z(\mu^+\mu^-)bb$ [2*HP+MET]	1 ± 1	2.6 ± 0.3	0.5 ± 0.05	0.0 ± 0.06	0.0 ± 0.04	2.1 ± 0.3

MC sample : 77% Z+b events

-> selection efficiency from MC : $\varepsilon_{MC} = 0.33$

Background not significant anymore

MET cut rejects ttbar background

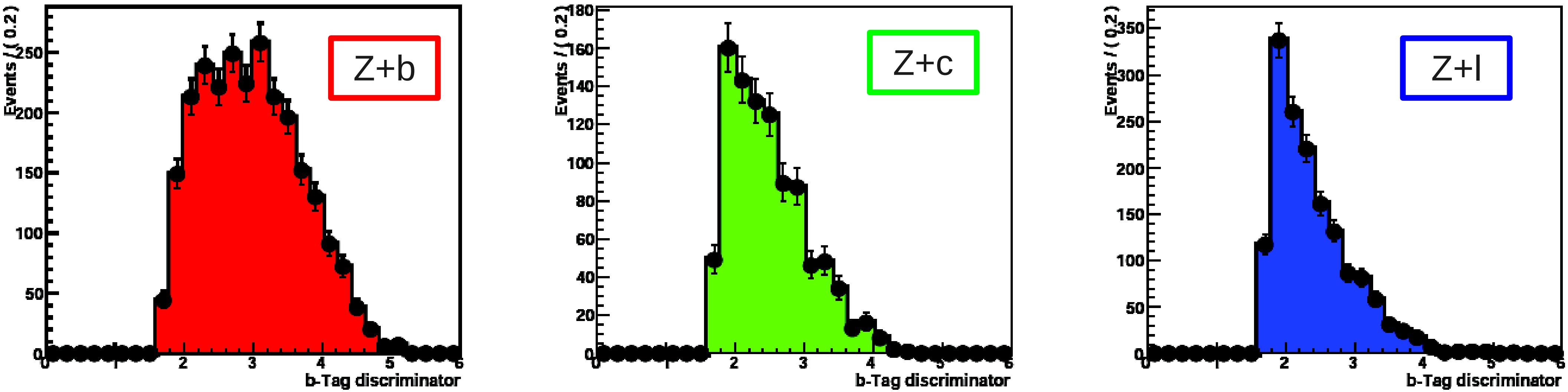
B tag rejects most DY and MC background

Purity from Data

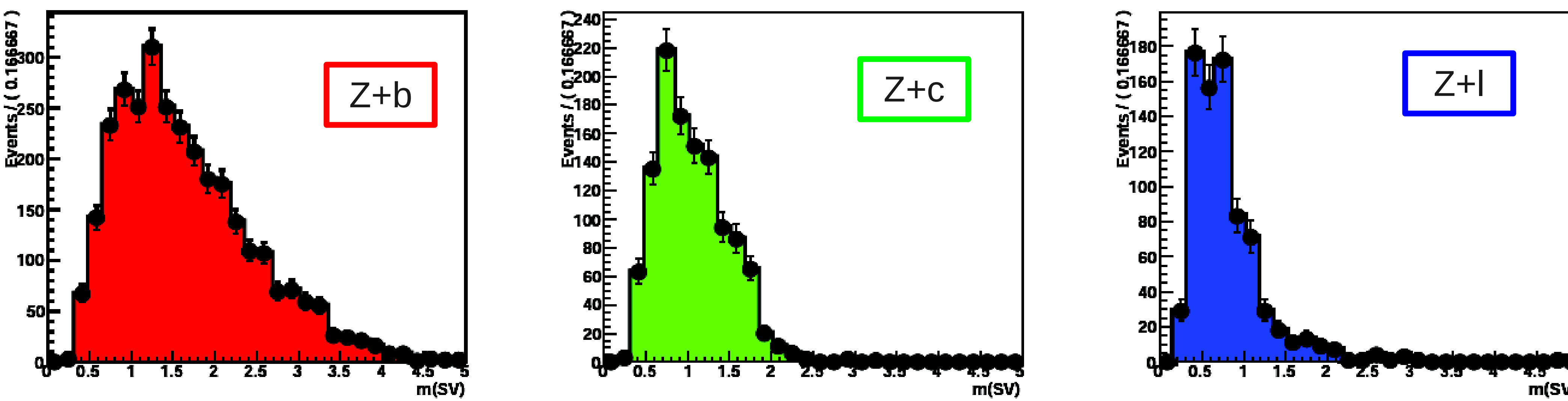
B tagging purity from MC = 82 %

Fit template with 2 variables to get btag P[HP] from data : long life time and heavy meson

✗ **B tag discriminator** :



✗ **Invariant Mass** :



Purity from Data
-> Fit Results

Extended likelihood fit for the number of events ->

WP	Fit model	N_b	N_c	N_l	$\mathcal{P}$
[HE]	b-tag-discr	76 ± 18	50 ± 55	10 ± 50	0.56 ± 0.13
[HE]	m(SV)	80 ± 16	39 ± 20	27 ± 12	0.55 ± 0.10
[HE]	MC	86.0 ± 1.8	31.6 ± 1.1	32.2 ± 0.8	0.57 ± 0.03
[HP]	b-tag-discr	55 ± 15	10 ± 21	1 ± 59	0.84 ± 0.20
[HP]	m(SV)	61 ± 12	4.2 ± 9.3	0.0 ± 2.1	0.93 ± 0.14
[HP]	MC	60.4 ± 1.5	11.3 ± 0.7	2.1 ± 0.2	0.82 ± 0.04

Two uncorrelated variables -> combination :

$$\boxed{\begin{aligned} \mathcal{P}(HE) &= 0.55 \pm 0.09 \\ \mathcal{P}(HP) &= 0.88 \pm 0.11. \end{aligned}}$$

(Z+b)/(Z+j)

Relative cross section
Small experimental uncertainties
Systematics = btag eff. + fake rate

$$\frac{\sigma(Z+b)}{\sigma(Z+j)} = \frac{N^{data}_{Z+b}\mathcal{P} - N^{MC}_{t\bar{t}}}{N^{data}_{Z+j}\varepsilon_{MC}}$$

	N^{data}_{Z+b}	$\mathcal{P}$	$N^{MC}_{t\bar{t}}$	N^{data}_{Z+j}	ε_{MC}	$(Z+b)/(Z+j)$ fraction
electrons, HP	29	0.88	1.6	1490	0.30	$5.4\% \pm 1.0\%$ (stat.) $\pm 1.2\%$ (syst.)
muons, HP	36	0.88	2.4	2141	0.30	$4.6\% \pm 0.8\%$ (stat.) $\pm 1.1\%$ (syst.)
electrons, HE	54	0.55	2.0	1490	0.43	$4.3\% \pm 0.6\%$ (stat.) $\pm 1.1\%$ (syst.)
muons, HE	91	0.55	3.0	2141	0.43	$5.1\% \pm 0.6\%$ (stat.) $\pm 1.3\%$ (syst.)

Theory + MCFM :

$$\left[\frac{\sigma(Z+b)}{\sigma(Z+j)}\right]_e = 4.3\% \pm 0.4\%,$$

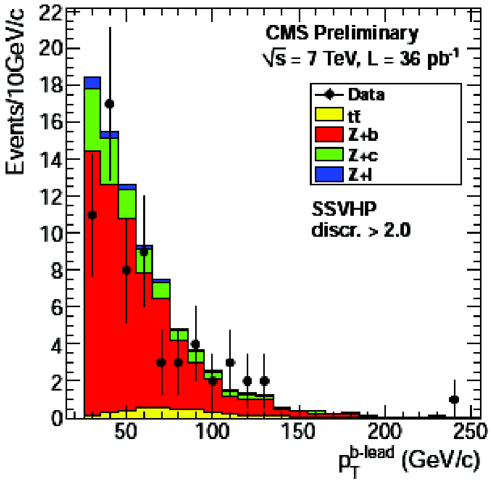
$$\left[\frac{\sigma(Z+b)}{\sigma(Z+j)}\right]_\mu = 4.7\% \pm 0.4\%$$

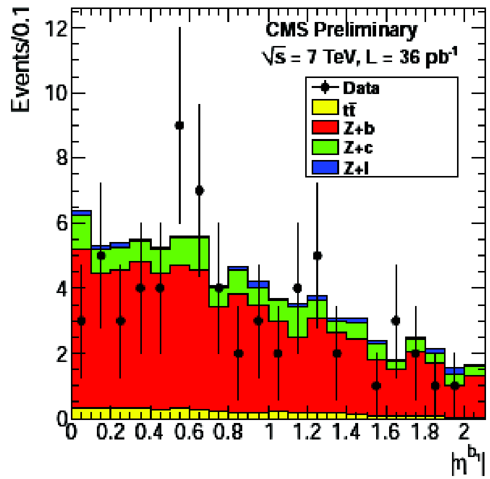
Signal properties

→ **Test Agreement with MC**
Validate the MC approach to estimate the yield

→ **Test key kinematic variables**

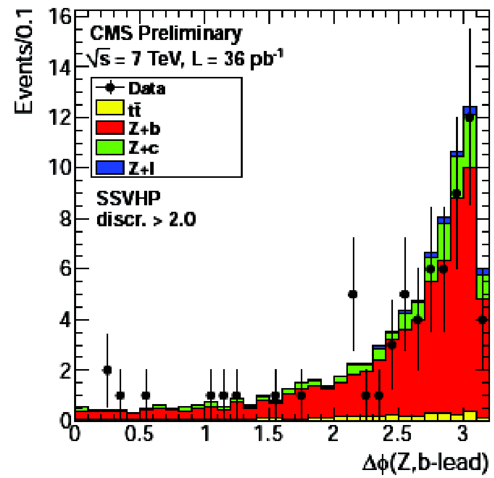
Z+b signal properties

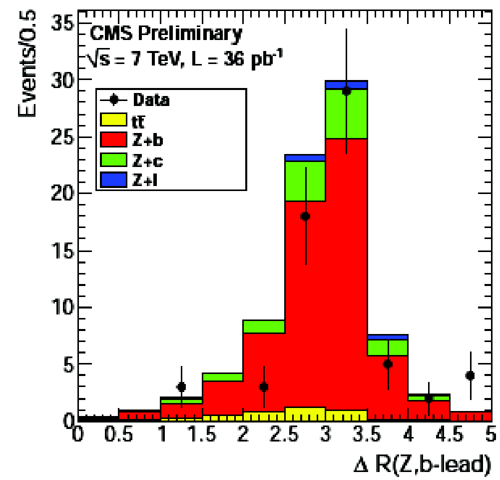


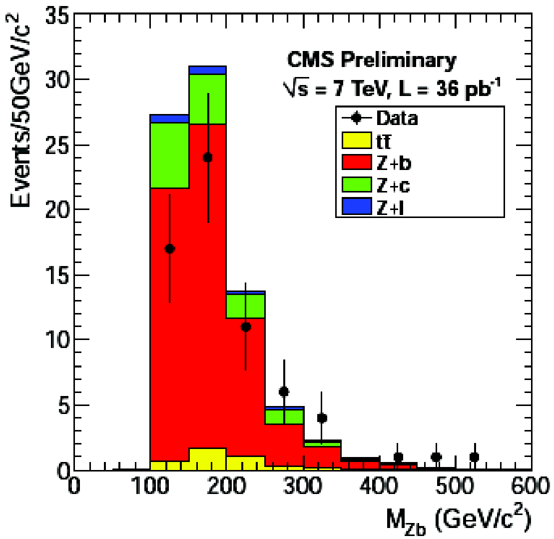


pT and eta of the leading bjet after Z+b [HP +MET] selection

Δφ and ΔR between Z and the leading bjet after Z+b [HP +MET] selection

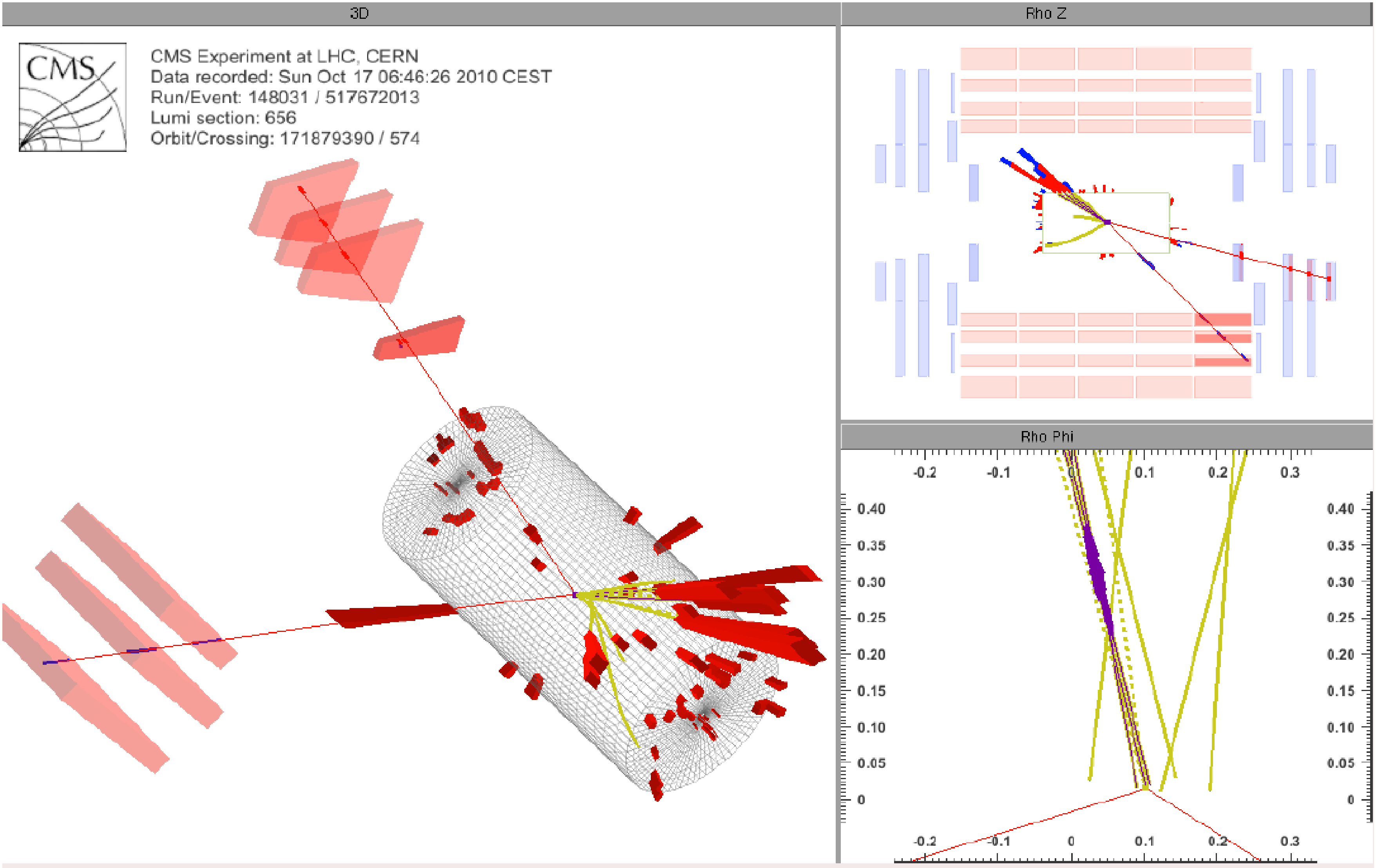






Invariant mass of Zb after Z+b [HP +MET] selection

Z+b event display



2 muons :
pTμ1 = 45.04 Gev
pTμ2 = 37.26 GeV

Mz = 90.7 GeV

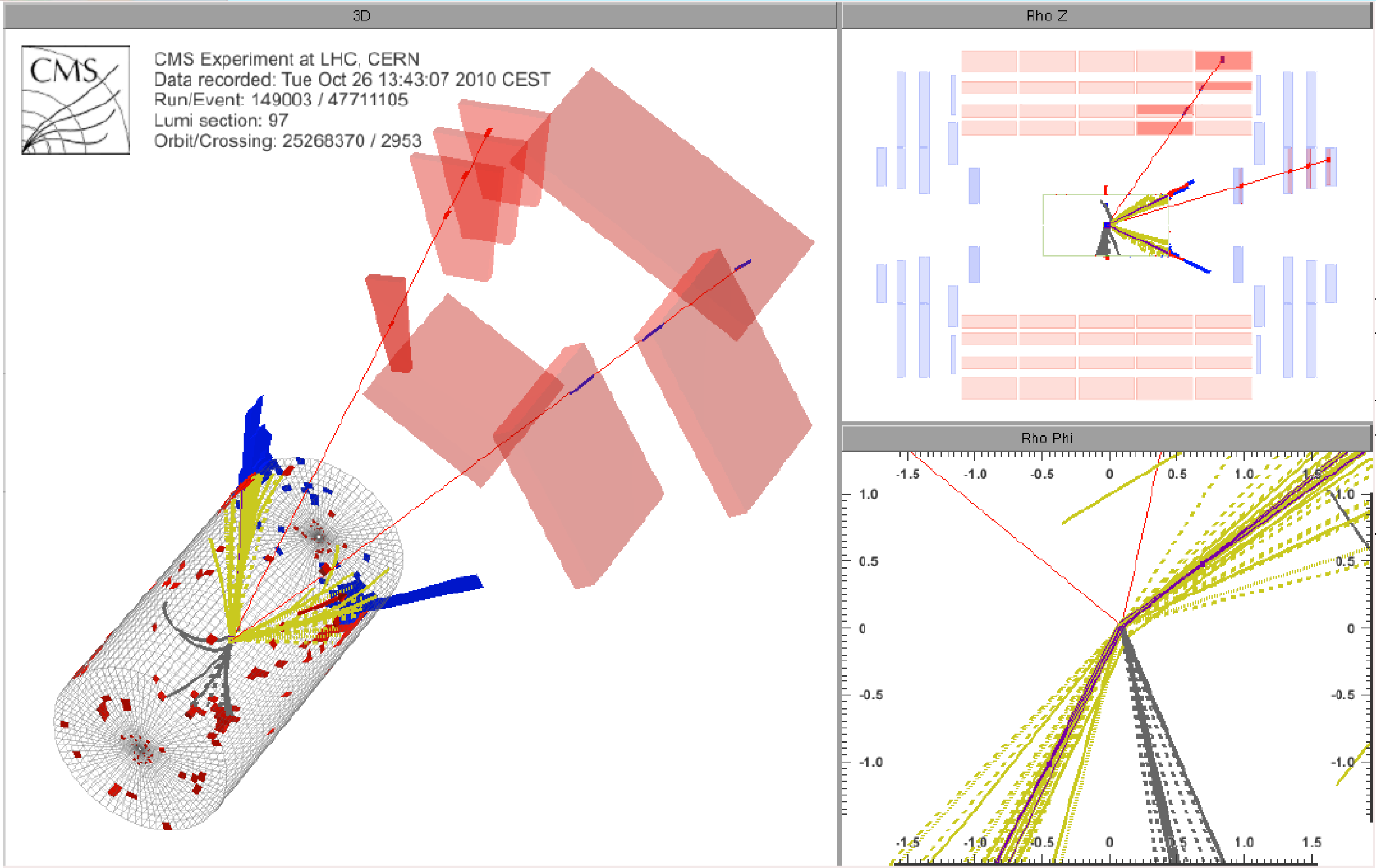
pT bjet = 28.4 GeV
back to back to Z

MET = 6.7 GeV

Run	148031	Event	517672013	Lumi Block	656
Object	p_T (GeV)	η	ϕ	SSVHE	SSVHP
jet 1	28.4	-1.19	1.73	2.83	2.83

Typical event

Zb(b) signal properties
Zμ(μ)bb event display



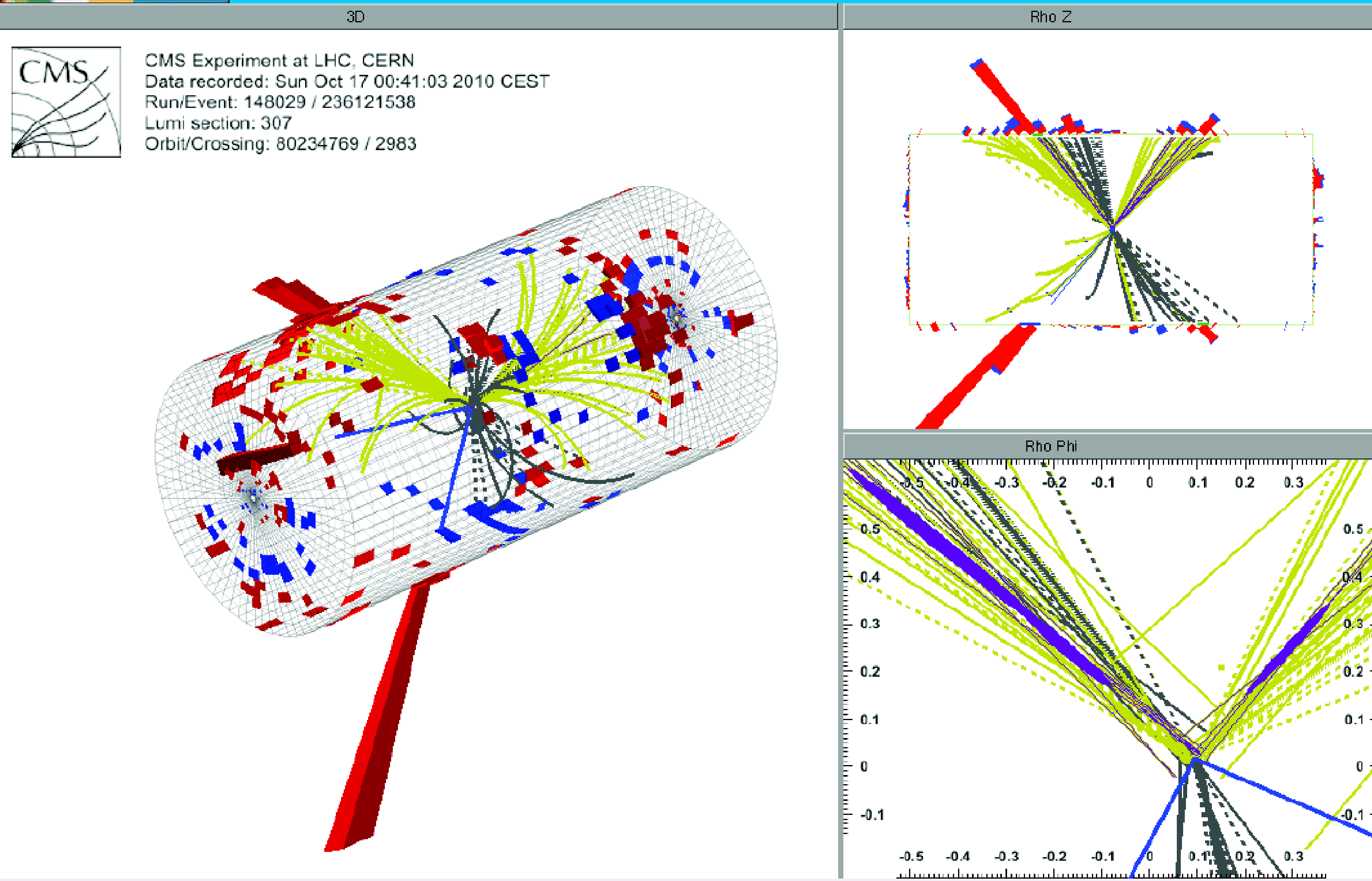
Object	p_T (GeV)
Muon 1	88.1
Muon 2	39.9
ME_T	34.3
Z	112
bb	103.3
Zbb	12.4

Run	149003	Event	47711105	Lumi Block	97
Object	p_T (GeV)	η	ϕ	SSVHE	SSVHP
jet 1	241	1.53	-2.06	3.17	3.17
jet 2	213	1.46	0.65	2.45	2.45
jet 3	40.2	-0.05	-1.34	-1	-1

Object	Mass (GeV)
M_{ll} (GeV)	102.4
M_{bb} (GeV)	454.4
M_{Zbb} (GeV)	628

High objects mass
High pT bjets

Zb(b) signal properties
Ze(e)bb event display



Object	p_T (GeV)
Electron 1	119.5
Electron 2	31.2
ME_T	12.5
Z	120.8
bb	137
Zbb	16.5

Run	148029	Event	236121538	Lumi Block	307
Object	p_T (GeV)	η	ϕ	SSVHE	SSVHP
jet 1	121	-0.784	0.834	2.7	2.7
jet 2	62.0	0.701	2.414	2.9	2.9
jet 3	42.2	-0.389	2.257	-1	-1
jet 4	36.1	0.663	-1.298	-1	-1

Object	Mass (GeV)
M_{ll}	90.3
M_{bb}	192
M_{Zbb}	400

High objects mass
High pT bjets

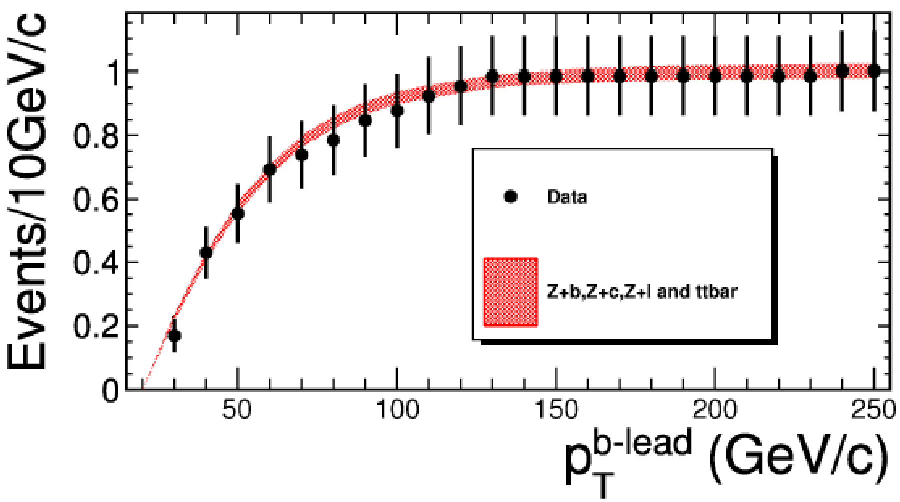
Cross-Checks

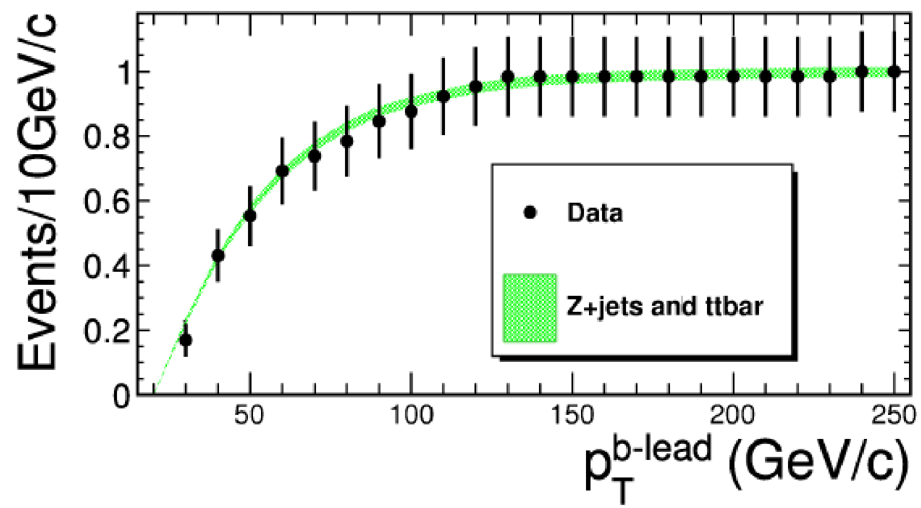
Effect of MC sheme

Z+b,Z+c,Z+l and ttbar ⟶ fixed flavor approach

Z+jets and ttbar ⟶ variable flavor approach

Normalized integral of the leading b-jet transverse momentum distribution for data and for MonteCarlo samples :





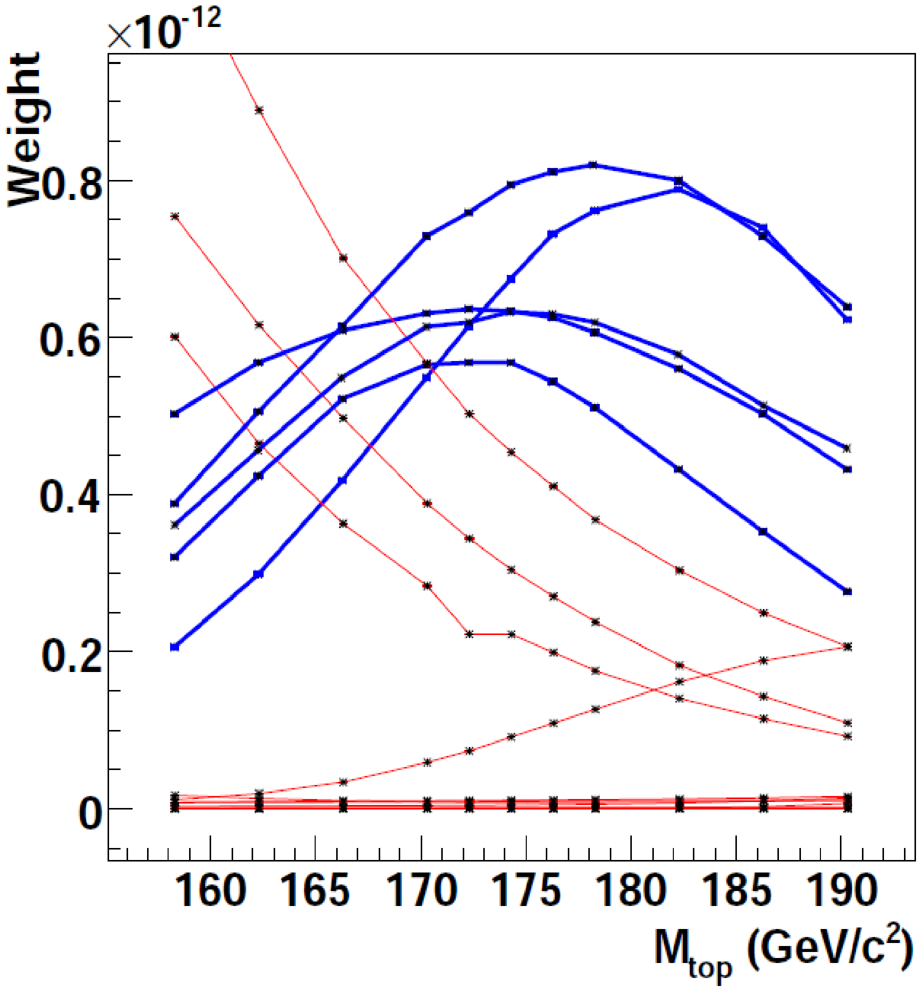
⟶ Good agreement between data and MonteCarlo
but not enough statistic to distinguish between the two different approches

ttbar evaluation from data

MadWeight Matrix Element Method

Proba to be produced for each event gives it a weight

$$P(x|\alpha) = \frac{1}{\sigma_\alpha} \int d\phi |M|^2_\alpha(y) W(x,y)$$



Zb[HP +MET] = 20 events with 2 jets
-> can be tested for ttbar hypothesis

5 events ttbar like
against 4 expected in Z->ee, μμ ,
Slide n°26

Good agreement

Can be use in the future to face pile up effect

First 2011 data

Settings 2011 data

- First data sample from 2011
- Using lumimasks :

  Mask 1: Cert_160404-161312_7TeV_PromptReco_Collisions11_JSON.txt
  - Luminosity: 5.07 pb-1

  Mask 2: /Cert_161079-161352_7TeV_PromptReco_Collisions11_JSON_noESpbl_v2.txt
  - Luminosity: 11.88 pb-1 PreShower Problems

- Datasets are skimmed on Dileptons -> 2 electrons or 2 muons without pT cuts
  selection cuts for quality of data taking

- Triggers = all triggers changed

  -> so far we are using all triggers lines both for selection and matching

  -> we will have Single Lepton Triggers Prescaled now

- CMSSW_4_1_3_patch2 + packages

Datasets
• /DoubleMu/Run2011A-PromptReco-v1/AOD • /DoubleElectron/Run2011A-PromptReco-v1/AOD

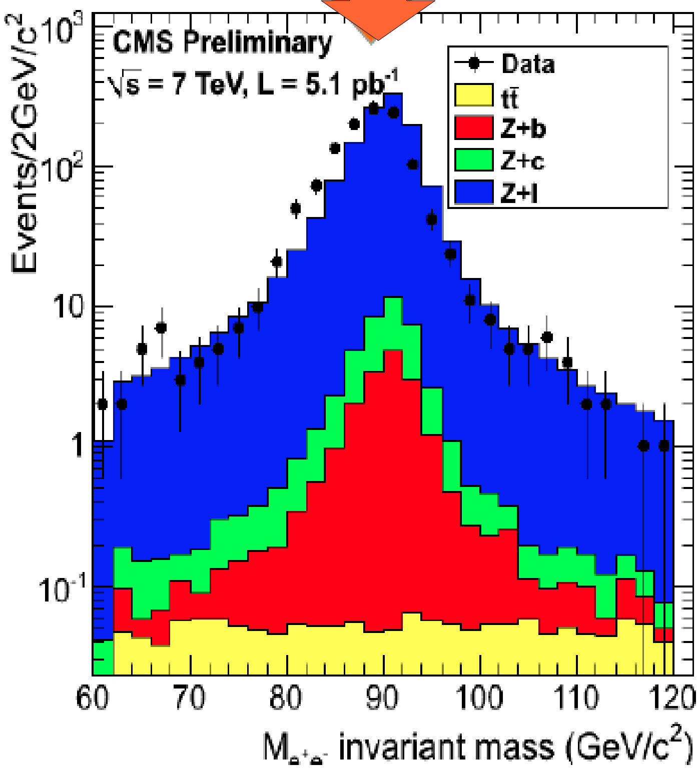
Yield 2011A$_{\text{Mask 5/pb}}$

Selection	Yield 2010 (36 pb-1)	Yield 2010 (scaled to 5.1 pb^{-1})	Yield ($2011A_1$) (5.1 pb^{-1})
Z(ee)	8982 ± 95	1261 ± 13	1239 ± 35
Z(ee)j	1490 ± 39	209 ± 5.5	199 ± 14
Z(ee)b [HE]	61 ± 8	8.6 ± 1.1	13 ± 4
Z(ee)b [HP+MET]	29 ± 5	4.1 ± 0.7	7 ± 3
Z(μμ)	11993 ± 110	1690 ± 16	1701 ± 41
Z(μμ)j	2141 ± 46	303 ± 6.5	326 ± 18
Z(μμ)b [HE]	104 ± 10	14.7 ± 1.4	16 ± 4
Z(μμ)b [HP+MET]	36 ± 6	5.1 ± 0.8	7 ± 3

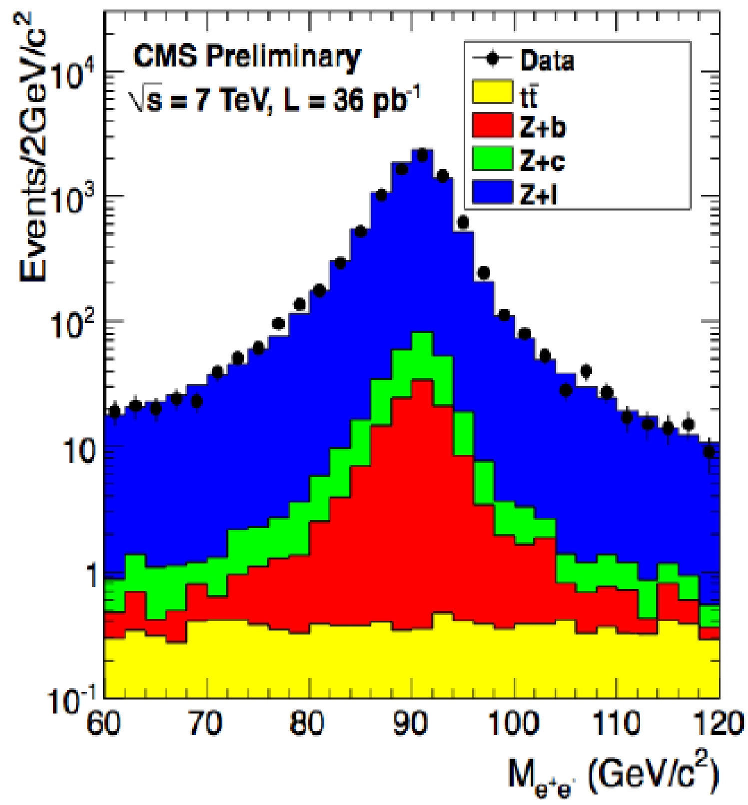
→ **GOOD AGREEMENT**

Me(e) after Z+j selection

Due to Prompt Reco ?



2011



2010

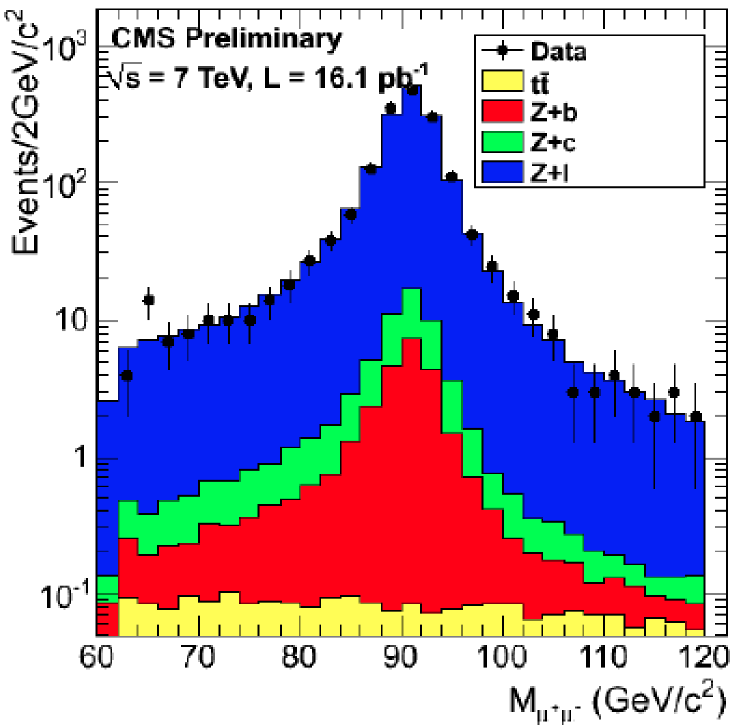
Yield 2011A Mask 5/pb+12/pb

Selection	Yield 2010 (36 pb-1)	"Yield 2010" (17 pb^{-1})	Yield (2011A$_{1+2}$) (17 pb^{-1})
Z(ee)	8982 ± 95	4242 ± 45	4051 ± 64
Z(ee)j	1490 ± 39	704 ± 18	747 ± 27
Z(ee)b [HE]	61 ± 8	29 ± 4	27 ± 5
Z(ee)b [HP+MET]	29 ± 5	13.7 ± 2.4	21 ± 5
Z(μμ)	11993 ± 110	5663 ± 52	5680 ± 75
Z(μμ)j	2141 ± 46	1011 ± 22	1171 ± 34
Z(μμ)b [HE]	104 ± 10	49 ± 5	44 ± 7
Z(μμ)b [HP+MET]	36 ± 6	17.0 ± 2.8	25 ± 5

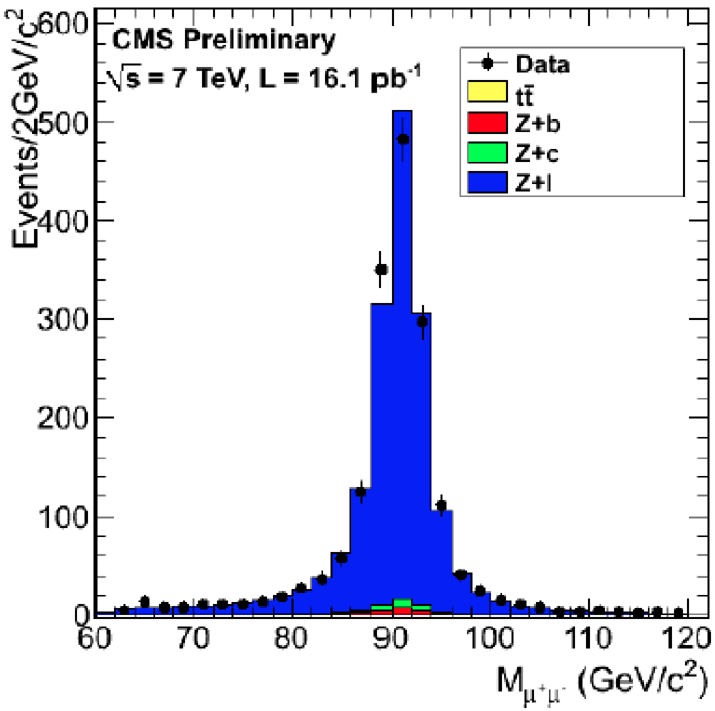
Slight inconsistencies

→ due to pile up ?

Mμ(μ) after Z+j selection



2011

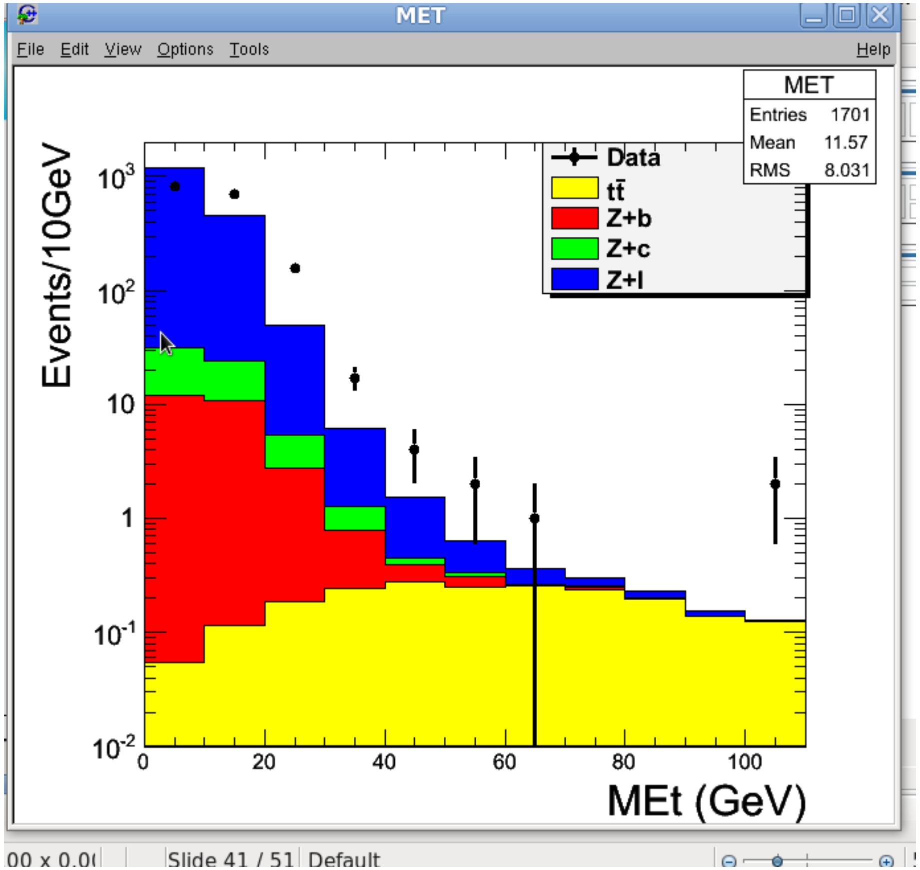


2011

→ **Perfect agreement**

Not affected by Pompt Reco or noES

Some keys distributions



Conclusions

- Running on the 2010 36/pb data already gives us nice agreement with MonteCarlo
- 2 Zbb events with unexpected kinematics

- 2011 data seem promising with new challenges (Pile up..)
- Z+b/Z+j ratio -> Next step = Z+b and Zbb cross section
  -> with 2011 data more statistics
  -> more systematics and efficiencies studies, involvement in b-tagging

- Zbb group might get larger and would like to present at Summer conference (EPS) and new paper by this fall
- ICHEP 2012...

Materiel References :

- PAS : EWK
- AN-10/409
- AN-10/405

Back-up

4 and 5 flavors diagrams

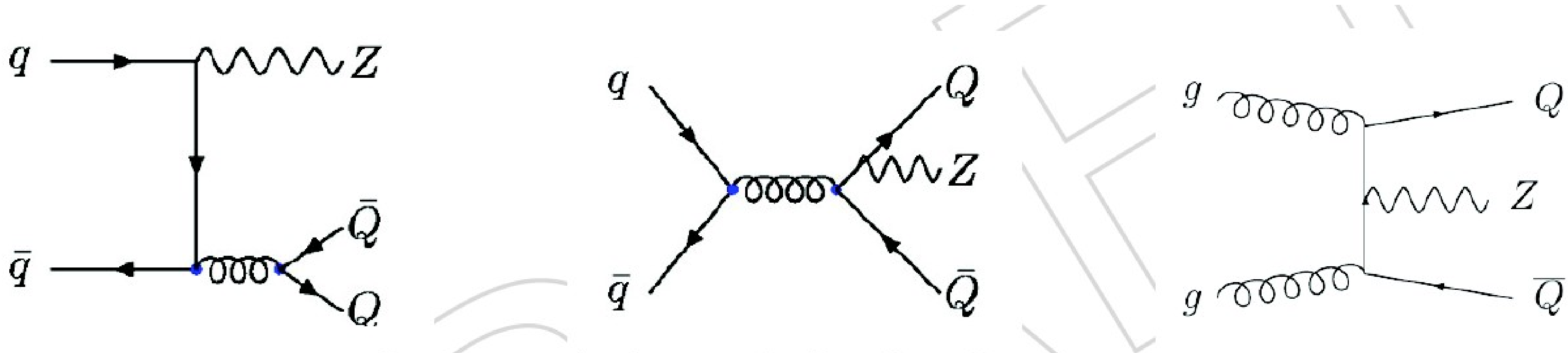


Figure 1: $q\bar{q}$,gg $\rightarrow$ Z+Q+$\bar{Q}$, with q = u, d, s, c and Q = b, c.

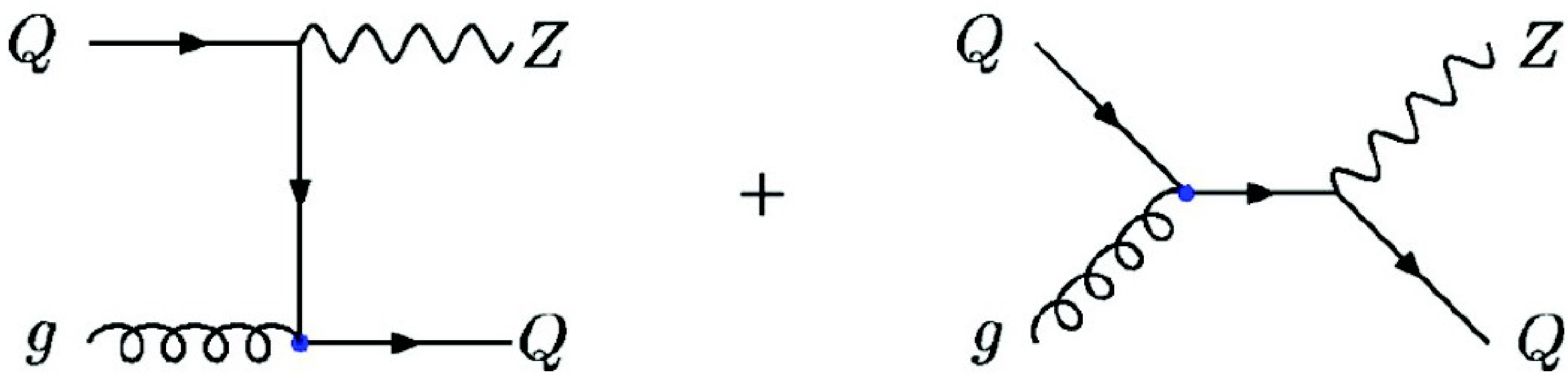


Figure 2: gq $\rightarrow$ Z+Q process, with Q = b, c.

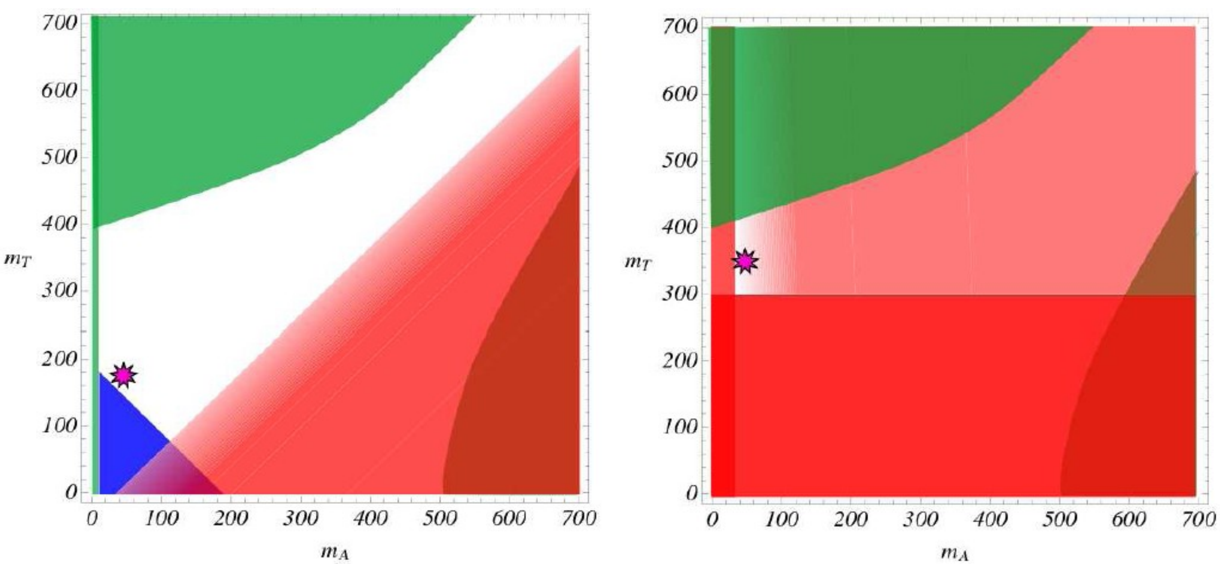
iM2HDM

Type	Constraint	Origin
I & II	$m_h < 500$ GeV/c^2	Unitarity
	$\sqrt{m_T^2 - m_A^2}$ <400 GeV/c^2	Perturbativity
	$m_{H^0} \sim m_{H^\pm}$	ΔT if m_h is large
	$m_A << m_T$	ΔS if m_h is large
	m_h >114 GeV/c^2	LEP direct constraint
I	$m_T + m_A$ >200 GeV/c^2	LEP $Zbbbb$
	$\tan\beta$ <0.5	B-physics
II	m_T >300 GeV	$b \to s\gamma$
	m_A >30 GeV/c^2	R_b at $\tan\beta \sim 30$
	m_A <100 GeV/c^2	a_μ
	m_A <70 GeV/c^2 if $\tan\beta > 35$	Tevatron bbA
	$\tan\beta > 2$	$B_0 - \overline{B}_0$ mixing
	$\tan\beta < 40$	$B \to \tau\nu$

A -> bb
Z -> ll

A low mass and H high masses to escapes the indirect constraints

Explain constraints!!
See Simon's thesis



(a) Type I (b) Type II

Triggers | Packages

Period	First run	lowest unpresc. single μ	lowest unpresc. single e
FirstCollisions2010	132440	HLT_Mu3	HLT_Photon10_L1R
TSG_24_VI_10	138564	HLT_Mu3	HLT_Photon15_Cleaned_L1R
TSG_13_VII_10	140058	HLT_Mu5	HLT_Photon15_Cleaned_L1R
TSG_03_VIII_10	141956	HLT_Mu7	HLT_Ele15_SW_CaloEleId_L1R
TSG_20_IX_10	146428	HLT_Mu9	HLT_Ele17_SW_CaloEleId_L1R
TSG_04_X_10	147146	HLT_Mu11	HLT_Ele17_SW_TightEleId_L1R
TSG_22_X_10	148783	HLT_Mu15_v1	HLT_Ele22_SW_TighterCaloIdIsol_L1R_v1
undefined	149181	HLT_Mu15_v1	HLT_Ele22_SW_TighterCaloIdIsol_L1R_v2

- `V00-03-00` `ElectroWeakAnalysis/WENu`
- `V08-03-10` `PhysicsTools/PatAlgos`
- `V00-03-19` `RecoEgamma/ElectronIdentification`
- `V1_2` `UserCode/zbb_louvain`

Selection Steps

1. Z(l+l-) selection: at least two leptons with opposite sign are combined into a Z-candidate.

2. Z(l+l-) + j selection: an event with a Z-candidate is required to have a ‘good’ jet in the Event.

3. Z(l+l-) + b [HE] selection: in the event with a Zj candidate the jet is required to have a value of the b-tag discriminating variable corresponding to the high-efficiency [HE] working point.

4. Z(l+l-) + b [HE+MET] selection: the event with Z+b candidate is required to have a missing ET MET < 40 GeV.

5. Z(l+l-) + b [HP+MET] selection: the b-jet in the Z+b candidate is required to have a value of the b-tag discriminating variable corresponding to the high-purity [HP] working Point.

6. Z(l+l-) + b [2*HP+MET] selection: a second b-jet is required to have a value of the b-tag 180 discriminating variable corresponding to the high-purity [HP] working point.

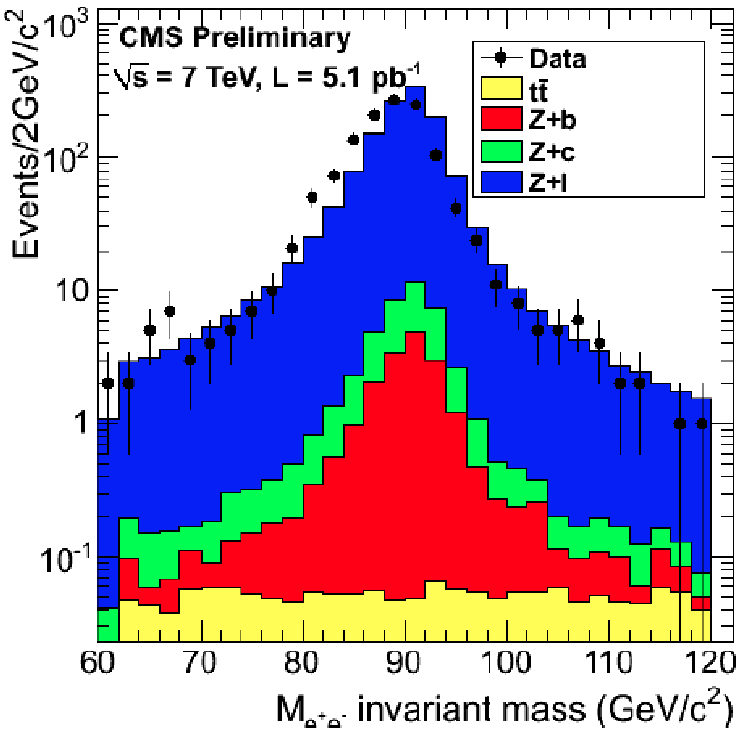
Selection with Z+j MC sample

Selection	2010 data	MC	$t\bar{t}$	$Z+j$
$Z(e^+e^-)$	8982 ± 95	9357 ± 14	10.7 ± 0.2	9346 ± 14
$Z(e^+e^-)j$	1490 ± 39	1534 ± 6	10.5 ± 0.2	1524 ± 6
$Z(e^+e^-)b$ [HE]	61 ± 8	70.9 ± 1.2	7.8 ± 0.2	63.1 ± 1.1
$Z(e^+e^-)b$ [HE+MET]	54 ± 7	64.2 ± 1.1	2.0 ± 0.1	62.2 ± 1.1
$Z(e^+e^-)b$ [HP+MET]	29 ± 5	30.1 ± 0.8	1.6 ± 0.1	28.5 ± 0.8
$Z(e^+e^-)bb$ [2*HP+MET]	1 ± 1	1.1 ± 0.1	0.4 ± 0.04	0.7 ± 0.1
$Z(\mu^+\mu^-)$	11993 ± 110	12228 ± 16	16.4 ± 0.3	12211 ± 16
$Z(\mu^+\mu^-)j$	2141 ± 46	2175 ± 7	16.0 ± 0.3	2159 ± 7
$Z(\mu^+\mu^-)b$ [HE]	104 ± 10	102.5 ± 1.4	11.9 ± 0.2	90.6 ± 1.4
$Z(\mu^+\mu^-)b$ [HE+MET]	91 ± 10	92.5 ± 1.4	3.0 ± 0.1	89.5 ± 1.4
$Z(\mu^+\mu^-)b$ [HP+MET]	36 ± 6	44.4 ± 0.9	2.4 ± 0.1	42.0 ± 0.9
$Z(\mu^+\mu^-)bb$ [2*HP+MET]	1 ± 1	1.6 ± 0.2	0.5 ± 0.05	1.1 ± 0.1

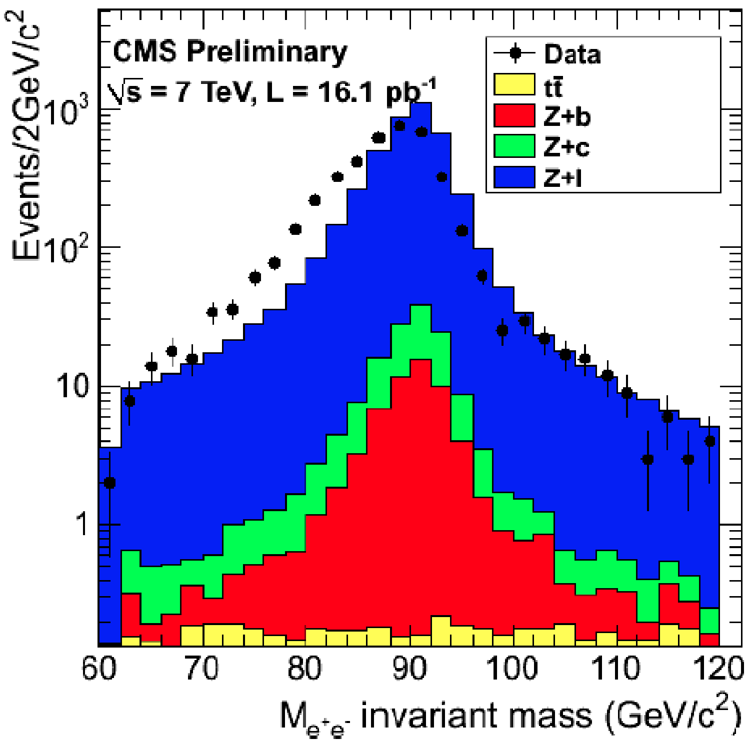
2011A$_{\text{Mask5/pb+12pb}}$ Data

Again M(ee)

- 2011A$_1$



- 2011A$_{1+2}$: no ES



- Discrepancy worse when including no-ES sample
  - As expected