BUE

Status of Z' Analysis in e- e+ channel

Sh. Elgammal[1]

[1]**British University in Egypt**

WP1 group (FP7 project)

22 / 01 / 2014

On going activities

(1) Angular distributions:

People involved

- Sh. Elgammal (BUE),
- P. Miné (LLR)
- B. Clerbaux (ULB),
- L. Thomas (ULB).

→ CMS AN -2013/361

(2) Recovery of Saturated ECAL crystals using MVA Method:

People involved

- Sh. Elgammal (BUE),
- P. Miné (LLR)
- B. Clerbaux (ULB).

→ AN on going

(3) **ECAL Spike in 14 TeV C.M.E**:

People involved

- M. Eshra (BUE),
- Sh. Elgammal (BUE),
- P. Miné (LLR)
- A. Zabi (LLR).

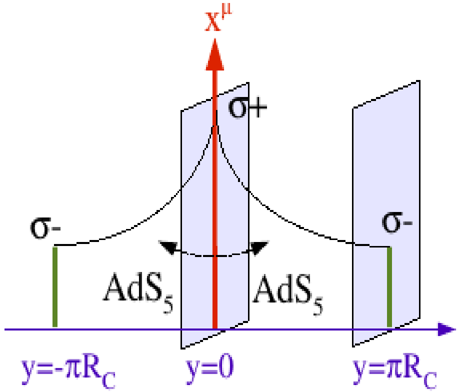
BSM Models

RS model of extra – dimensions

[Phys.Rev.Lett. 83 (1999) 3370 - hep-ph/9905221]

1 ED compactified, constant and negative curvature space (AdS_5):

bounded by 2 branes: Planck brane (y=0) and TeV or SM brane ($y=\pm\pi R_C$)



$m \rightarrow m e^{-\pi k R_c}$

metric: (non factorizable)

$$ds^2 = e^{-2ky}\, \eta_{\mu\nu}\, dx^\mu dx^\nu - dy^2$$

$R_5 = -20\, k^2$

Gauss law: relates M_D to M_{Pl}:

$$\overline{M}^2_{Pl} = \frac{M^3_D}{k}(1 - e^{-2\pi k R_c})$$

The scale of phys. phen. as realized by 4D flat metric ⊥ to 5th dim:

$\sim 10^{18}$ GeV → 1 TeV need $kR_C \sim 11$

→ $R_C \sim 10^{-32}$ m (very small)

$$\Lambda_\pi = \overline{M}_{Pl}\, e^{-k\pi R_c}$$

No hierarchy: $k \sim M_D \sim M_{Pl}$

consistency SM:

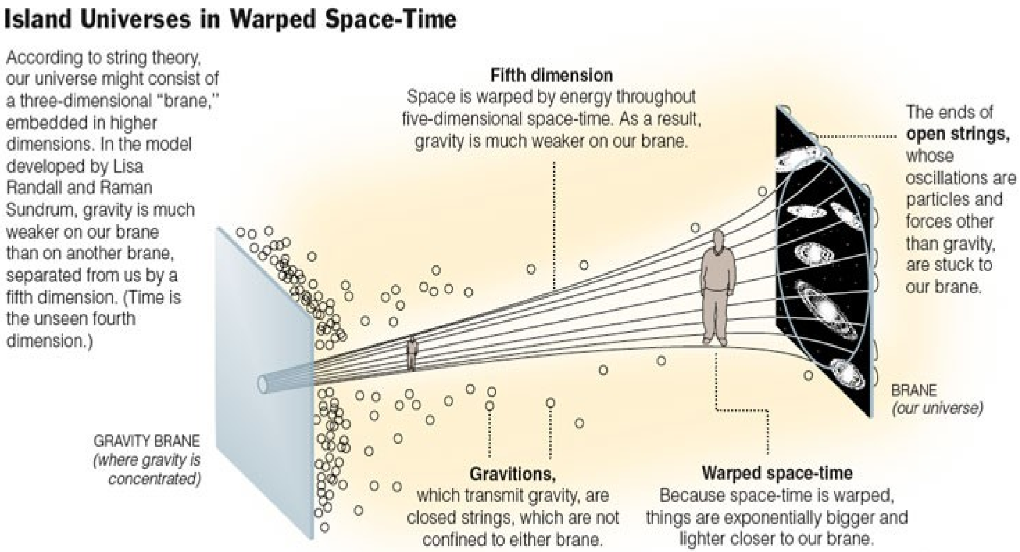
$k < M_D$ ($k <= 0.1 M_D$)

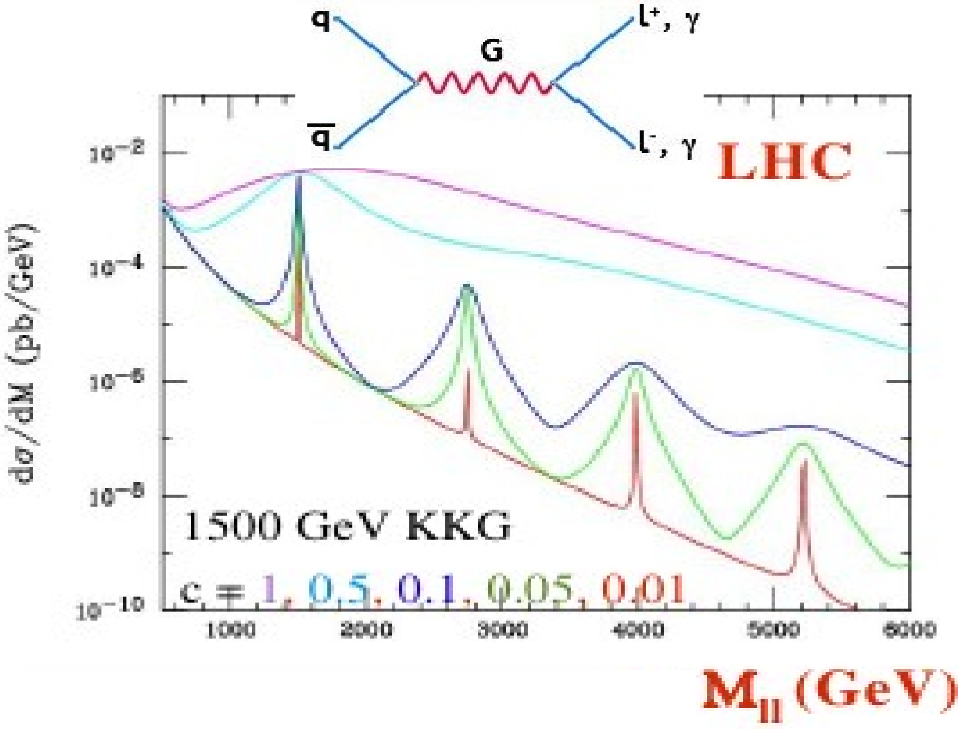
$k < 0.1 M_{Pl}$

2 free parameters: m_1 or Λ_π and $k/M_{Pl} = c$

width: $\sim (k/M_{Pl})^2$

$\sim m_n^3$





Theory of Grand Unification (Z')

E_6 is GUT group of rank 6:

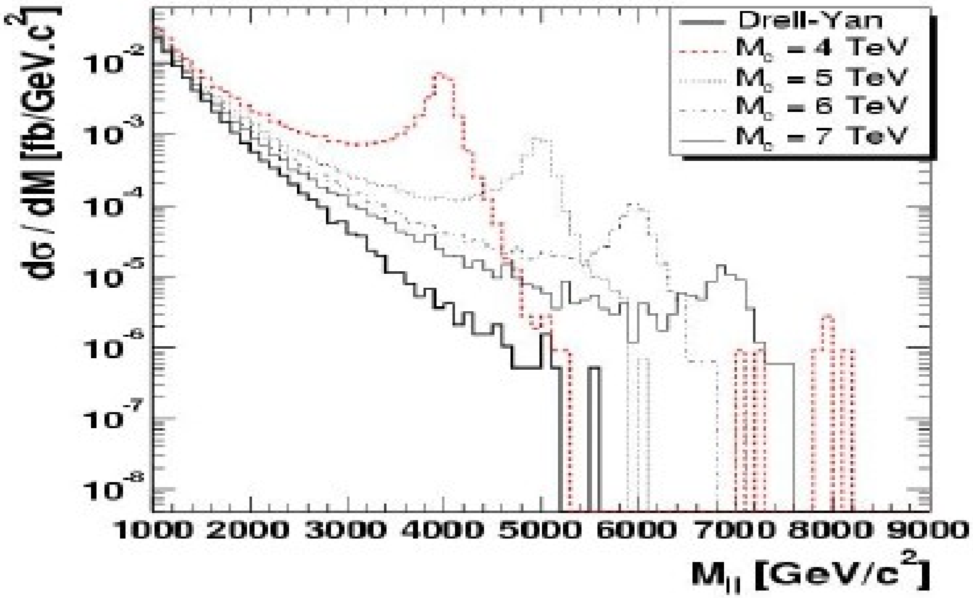
$$E_6 \to SO(10) \times U(1)_\psi \to SU(5) \times U(1)_\chi \times U(1)_\psi$$
$$\to SU(3)_C \times SU(2)_L \times U(1)_Y \times U(1)' , \quad (2.2)$$

where $U(1)'$ is a linear compination of $U(1)_\chi$ and $U(1)_\psi$, thus

$$U(1)' = U(1)_\chi \cos(\theta) + U(1)_\psi \sin(\theta) , \quad (2.3)$$

where θ, for E_6, is a free parameter [17]; if $\theta = 0$, one extra gauge boson Z'_χ exists from $SO(10)$, while for $\theta = \pi/2$ only Z'_ψ from E_6 is obtained. Finally, $U(1)_\eta$ is a particular combination of $U(1)_\chi$ and $U(1)_\psi$, i.e., $\theta = 2\pi - \tan^{-1}\sqrt{5/3}$, which produces Z'_η [17]. The additional neutral Z boson is more massive than the SM

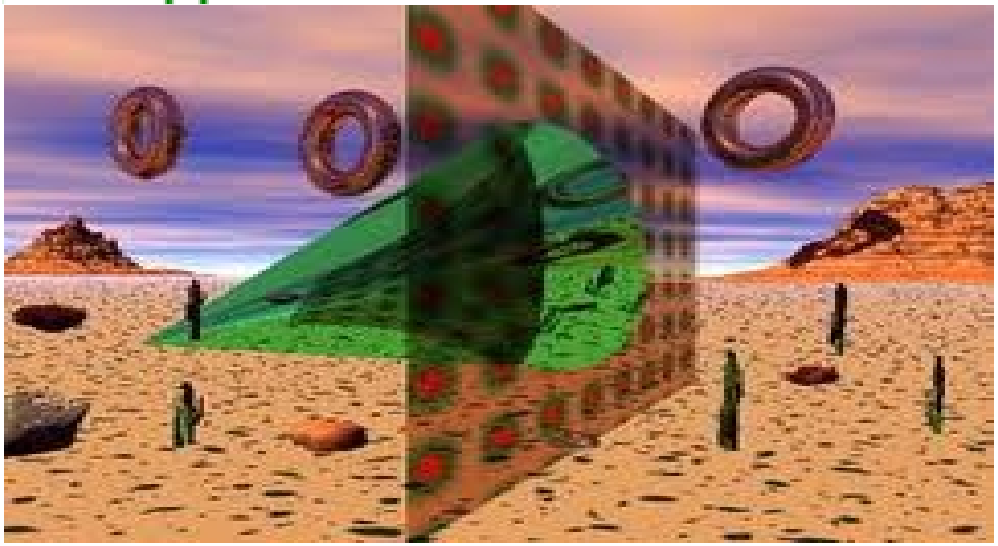
[Rizzo, PRD61(2000) 055005)]



ADD model of extra – dimensions

ADD: Arkadi-Hamed, Dimopoulos and Dvali

[Phys.Lett. B429 (1998) 263 - hep-ph/9803315]



Gauss law: relates M_D to M_{Pl} :

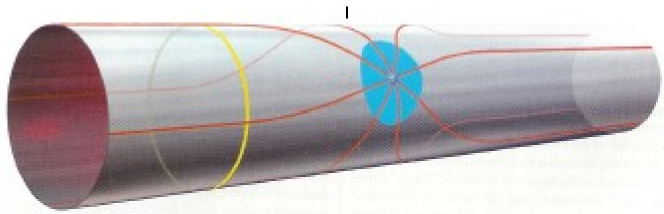
$$r \ll R_C \quad \rightarrow V_{4+\delta}(r) = -\frac{1}{M_D^{2+\delta}} \frac{m}{r^{\delta+1}}$$

$$r \gg R_C \quad \rightarrow V_4(r) = -\frac{1}{M_D^{2+\delta}(2\pi R)^\delta} \frac{m}{r}$$

$$M_{Pl}^2 = V_\delta M_D^{2+\delta}$$

$$V = (2\pi R_c)^\delta$$

Dimension



Coupling ~ $1/M_{Pl}$ - but $N = (ER_c)^\delta$

for $\delta=2$ and E=1 TeV $\rightarrow 10^{30}$ KK gravitons

if $M_D = 1$ TeV : $R \sim 10^{(30/d-17)}$ cm

Experim. searches: - high energy collider

[- astrophysics]

- short range gravity experiments

Contact interaction model

The differential cross section corresponding to the combination of a single term in Eq. 1 with DY production can be written as

$$\frac{d\sigma^{CI/DY}}{dM_{\mu\mu}} = \frac{d\sigma^{DY}}{dM_{\mu\mu}} - \eta_{ij}\frac{\mathcal{I}}{\Lambda^2} + \eta_{ij}^2\frac{\mathcal{C}}{\Lambda^4}, \quad (2)$$

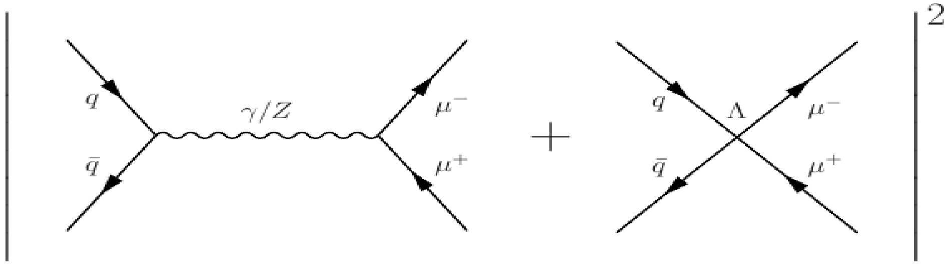
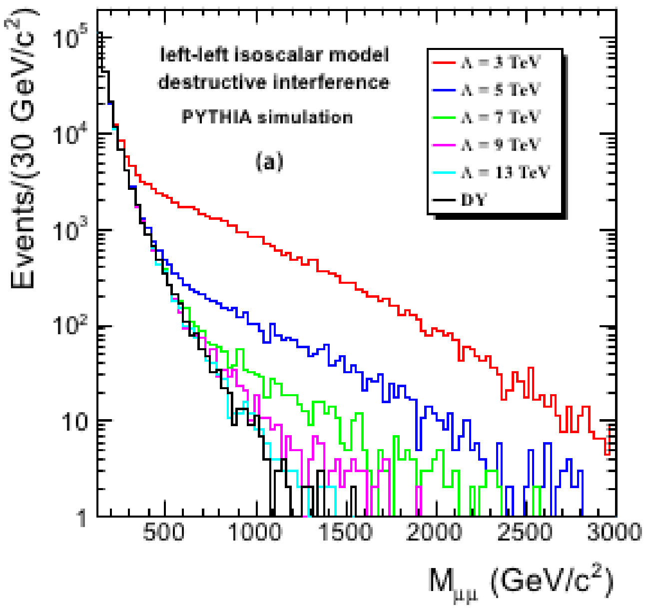
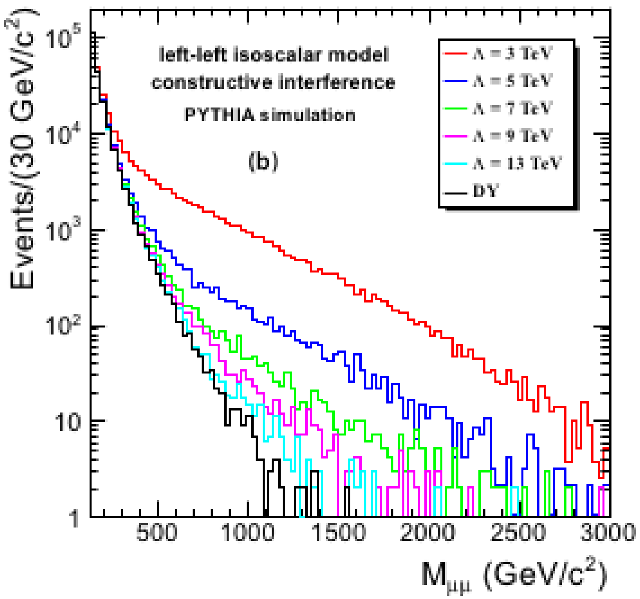


Figure 1: Schematic representation of the addition of DY (left) and CI (right) amplitudes, for common helicity states, contributing to the total cross section for $pp \to X + \mu^+\mu^-$.





MC & Data sets

The Summer12 (reconstructed with CMSSW software, version 5.3.x) Monte Carlo simulated samples are used:
(1) for background samples;
/DYToEE-M-20-CT10-TuneZ2star-8TeV-powheg-pythia6/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/DYToEE-M-120-CT10-TuneZ2star-8TeV-powheg-pythia6/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/DYToEE-M-200-CT10-TuneZ2star-8TeV-powheg-pythia6/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/DYToEE-M-400-CT10-TuneZ2star-8TeV-powheg-pythia6/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/DYToEE-M-500-CT10-TuneZ2star-8TeV-powheg-pythia6/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/DYToEE-M-700-CT10-TuneZ2star-8TeV-powheg-pythia6/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/DYToEE-M-800-CT10-TuneZ2star-8TeV-powheg-pythia6/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/DYToEE-M-1000-TuneZ2star-8TeV-pythia6/Summer12-PU-S7-START52-V9-v1/AODSIM,
/DYToEE-M-2000-CT10-TuneZ2star-8TeV-powheg-pythia6/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/TT-CT10-TuneZ2star-8TeV-powheg-tauola/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/WW-TuneZ2star-8TeV-pythia6-tauola/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/WZ-TuneZ2star-8TeV-pythia6-tauola/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/ZZ-TuneZ2star-8TeV-pythia6-tauola/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/DYToTauTau-M-20-CT10-TuneZ2star-8TeV-powheg-pythia6/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/T-tW-channel-DR-TuneZ2star-8TeV-powheg-tauola/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM.

(2) for signales samples;
/RSGravEE-kMpl001-M-2000-TuneZ2star-8TeV-pythia6/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/ZprimePSIToEE-M-2000-TuneZ2star-8TeV-pythia6/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/ADDdiLepton-LambdaT-2000-Tune4C-8TeV-pythia8/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,
/CIToEE-Con-Lambda-13-M-800-TuneZ2star-8TeV-pythia6/Summer12-DR53X-PU-S10-START53-V7A-v1/AODSIM,

Dataset	run range	json file
Run2012A-13Jul2012	190456-193621	Cert_190456-196531_8TeV_13Jul2012ReReco_Collisions12_JSON_v2.txt
Run2012A-recover-06Aug2012	190782-190949	Cert_190782-190949_8TeV_06Aug2012ReReco_Collisions12_JSON.txt
Run2012B-13Jul2012	193833-196531	Cert_190456-196531_8TeV_13Jul2012ReReco_Collisions12_JSON_v2.txt
Run2012C-ReReco	198022-198913	Cert_198022-198523_8TeV_24Aug2012ReReco_Collisions12_JSON.txt
Run2012C-PromptReco-v2	198934-203746	Cert_190456-203002_8TeV_PromptReco_Collisions12_JSON_v2.txt
Run2012C-EcalRecover$_1 1Dec$2012	201191-201191	Cert_201191-201191_8TeV_11Dec2012ReReco-recover_Collisions12_JSON.txt
Run2012D-PromptReco-v1	203768-208686	Cert_190456-206098_8TeV_PromptReco_Collisions12_JSON.txt

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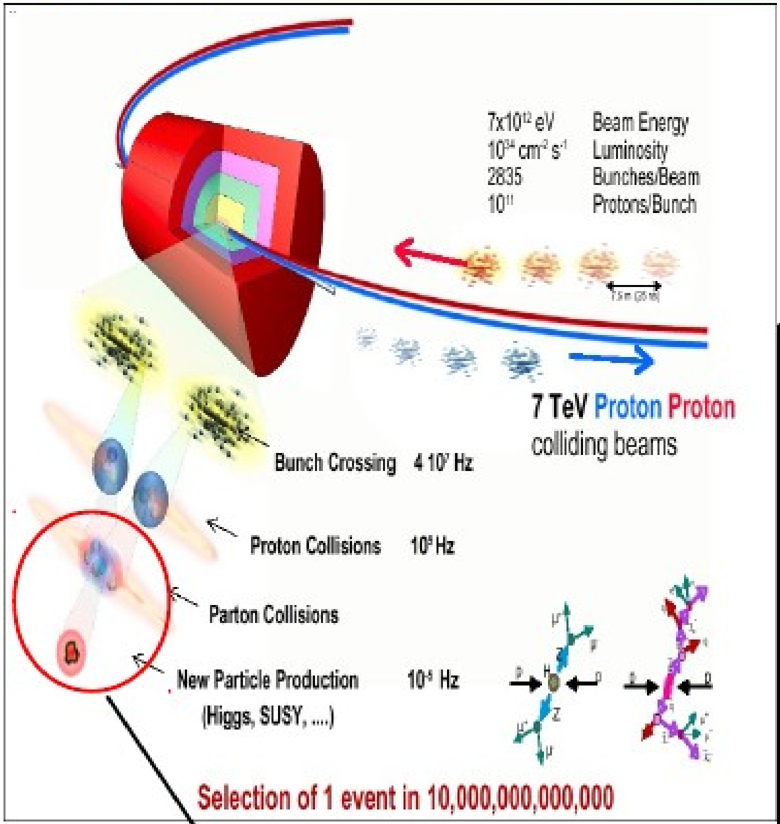
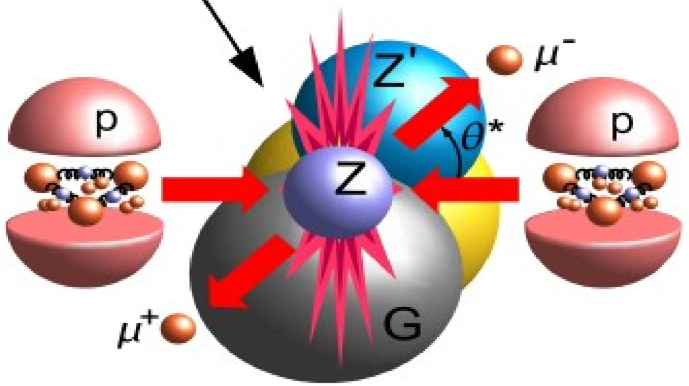
Event Selection (HEEP)

Cut group	variable	barrel	endcap
Kinematics cuts	E_T	> 35 GeV	> 35 GeV
	$\lvert\eta_{SC}\rvert$	< 1.442	$1.56 < \lvert\eta\rvert < 2.5$
	seed	ECAL seeded	ECAL seeded
	missing hits	<=1	<=1
	$\lvert d_{xy}\rvert$	<0.02	<0.05
	$\Delta\eta_{in}$	< 0.005	< 0.007
Shower shape cuts	$\Delta\phi_{in}$	< 0.06	<0.06
	H/E	< 0.05	< 0.05
	E^{2x5}/E^{5x5}	> 0.94 OR $E^{1x5}/E^{5x5} > 0.83$	-
	$\sigma_{i\eta i\eta}$	-	< 0.03
Isolation cuts	isol Em + Had Depth 1	$< 2 + 0.03 \times E_T + \rho \times 0.28$ GeV	< 2.5 GeV $+\rho \times 0.28$ for $E_T < 50$ GeV $< 2.5 + 0.03 \times (E_T - 50) + \rho \times 0.28$ GeV
	isol Pt Tracks	< 5 GeV/c	< 5 GeV/c

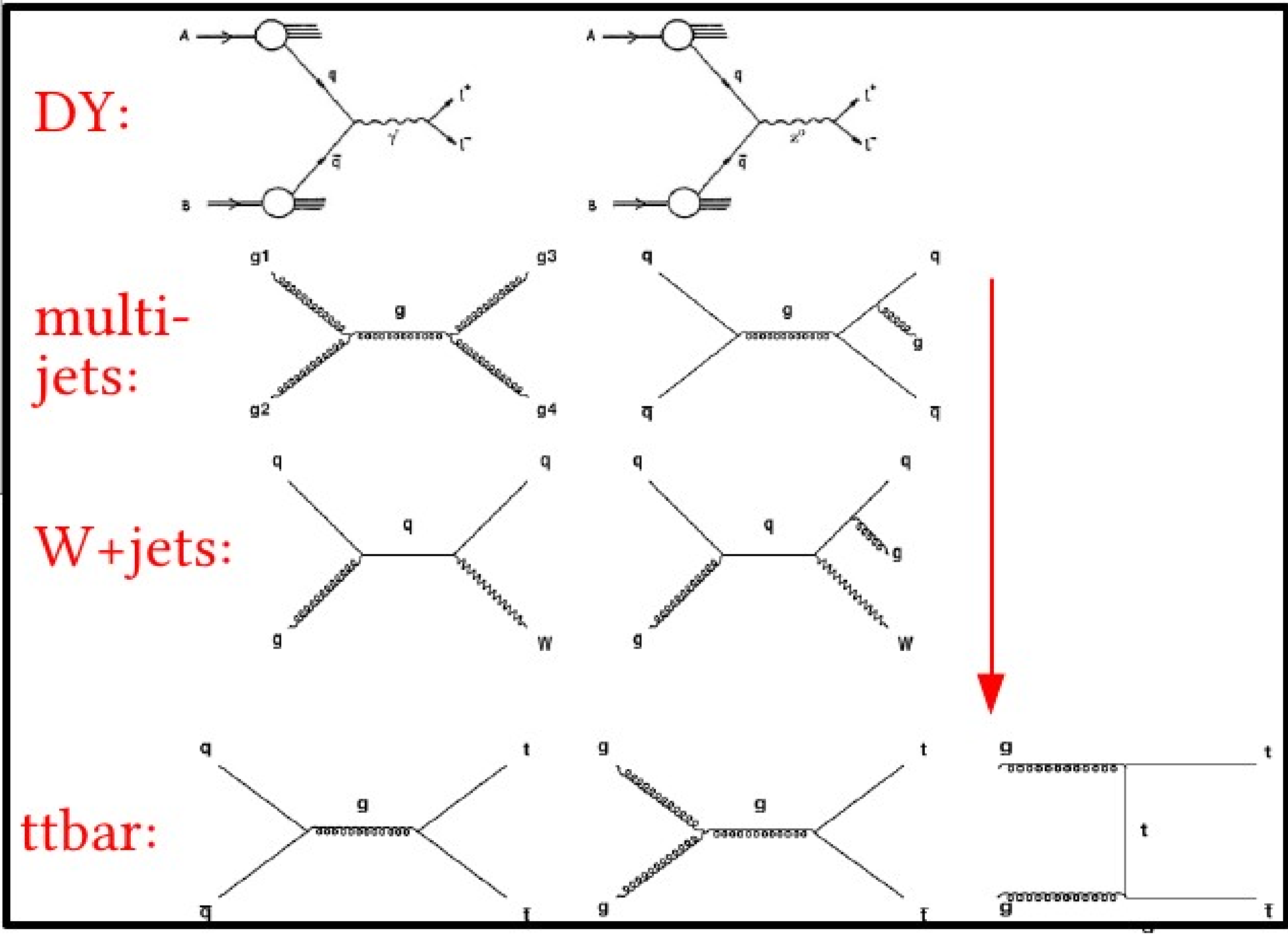
* HEEP events are selected with 2 opposite sign electrons
* Events with 2 electrons reco in EE are excluded

Physics I am interested in !





Backgrounds



Bosons Kinematics at Lab Frame

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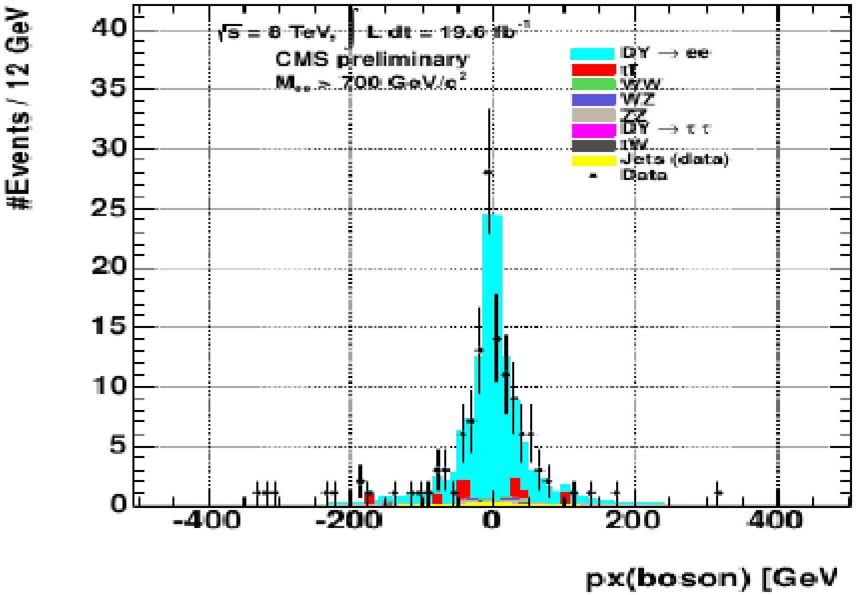
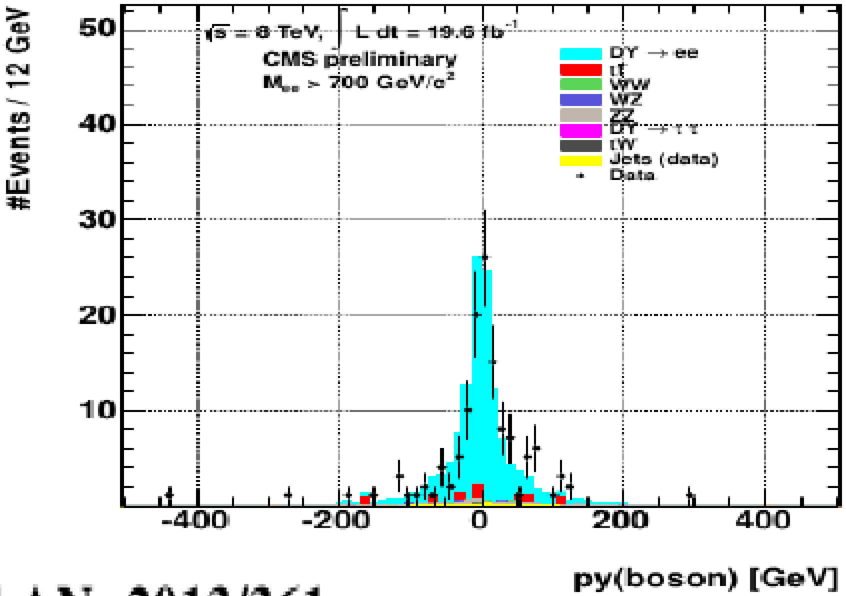
Boson kinematics at high mass





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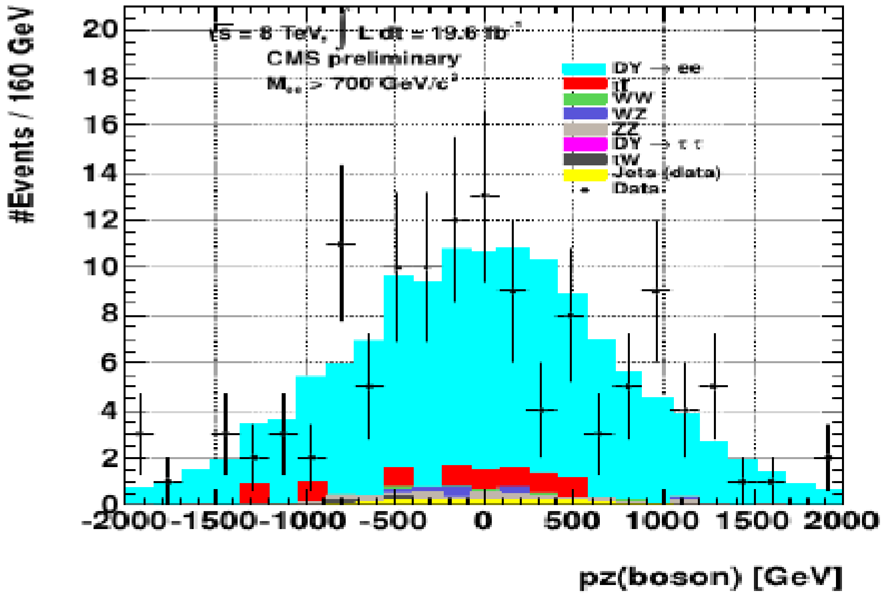
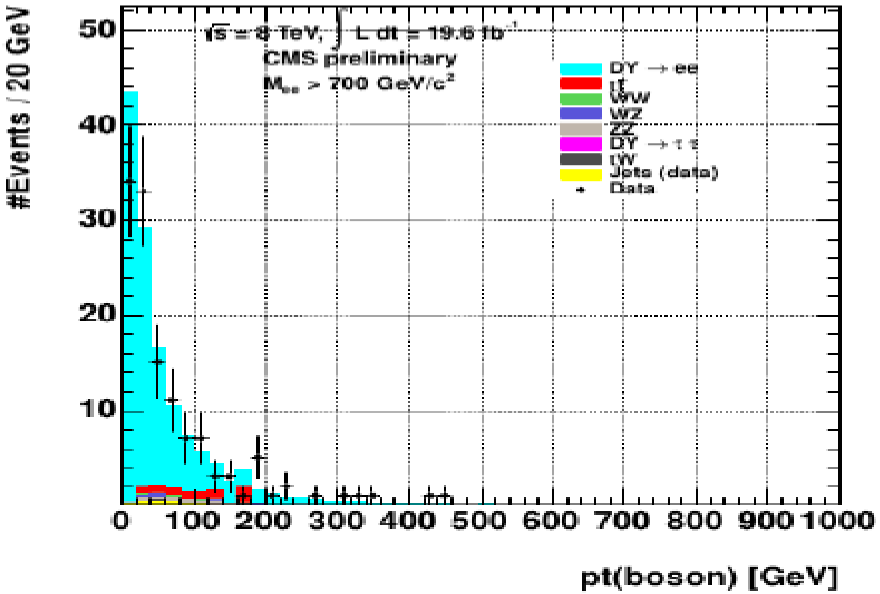
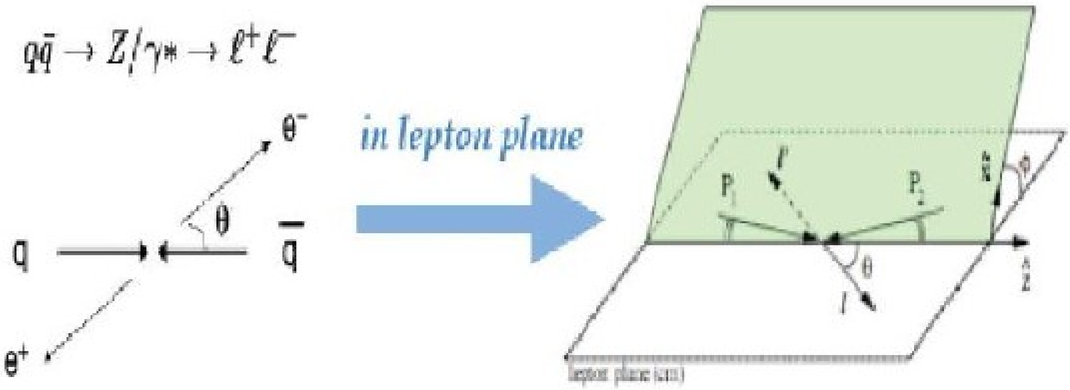




Collins Soper Frame



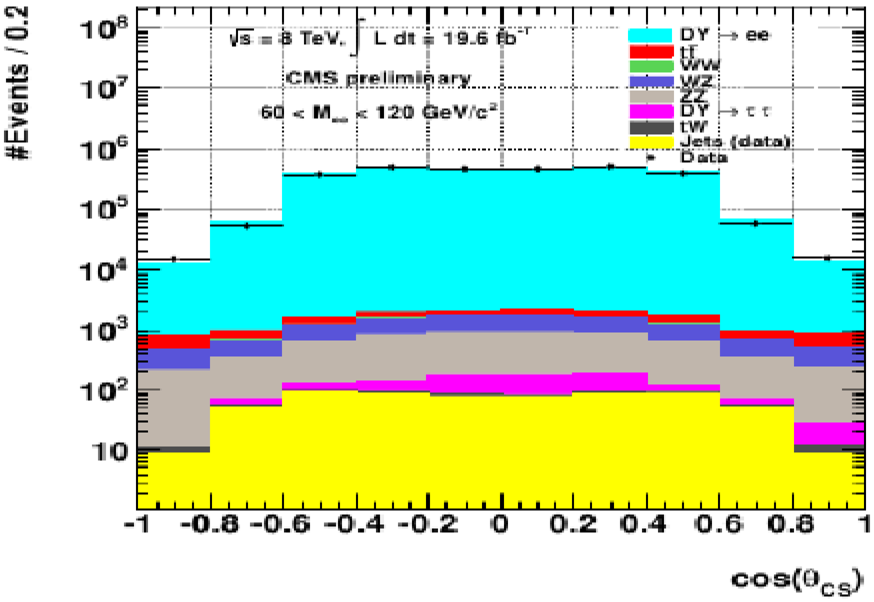
http://arxiv.org/pdf/1207.3973v1.pdf

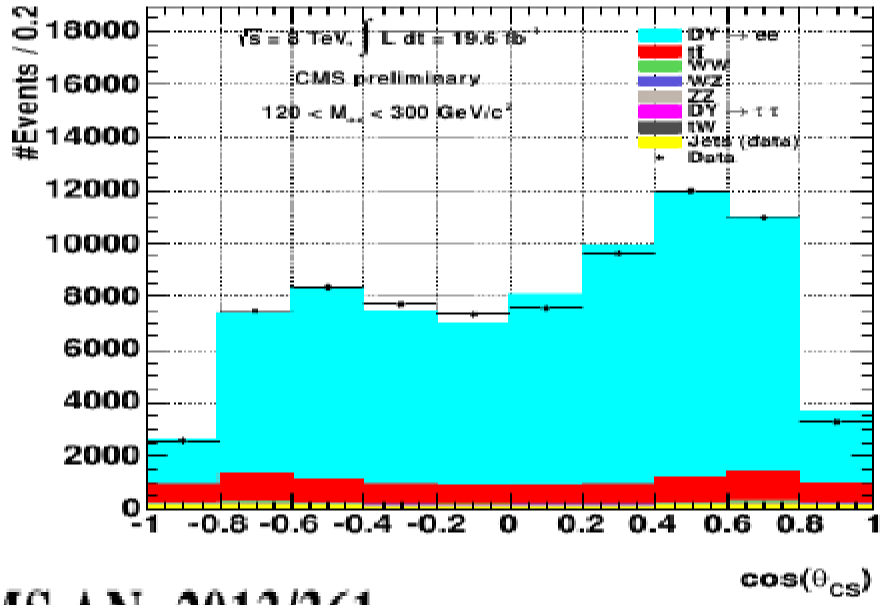
Figure 5: Collins Soper frame is characterized by 2 properties; the y axis is perpendicular to the plane spanned by the two hadron momenta P_1 and P_2, the z-axis bisects the proton and minus the other proton directions in the boson rest frame.

$$\cos\theta^*_{CS} = \frac{Q_z}{|Q_z|}\frac{2(P_1^+P_2^- - P_1^-P_2^+)}{|Q|\sqrt{Q^2+Q_T^2}}, \quad (3)$$

where Q is the four-momentum of the dilepton and Q_T and Q_z are the transverse and longitudinal components of the dilepton momentum with respect to the beam axis; P_1 (P_2) represents the four-momentum of the lepton (antilepton); and $P_i^\pm = (P_i^0 \pm P_i^3)/\sqrt{2}$. The quark direction is not determined a priori at the Large Hadron Collider (LHC) [13] because both beams consist of protons. However, because the antiquark is necessarily a sea quark, on average we expect it to carry less momentum than the valence quark, and therefore the dilepton system is usually boosted in the direction of the valence quark [5, 14, 15]. This assumption is taken into account by including the sign of the longitudinal boost in the definition of $\cos\theta^*_{CS}$.

Angular distributions for DY dist





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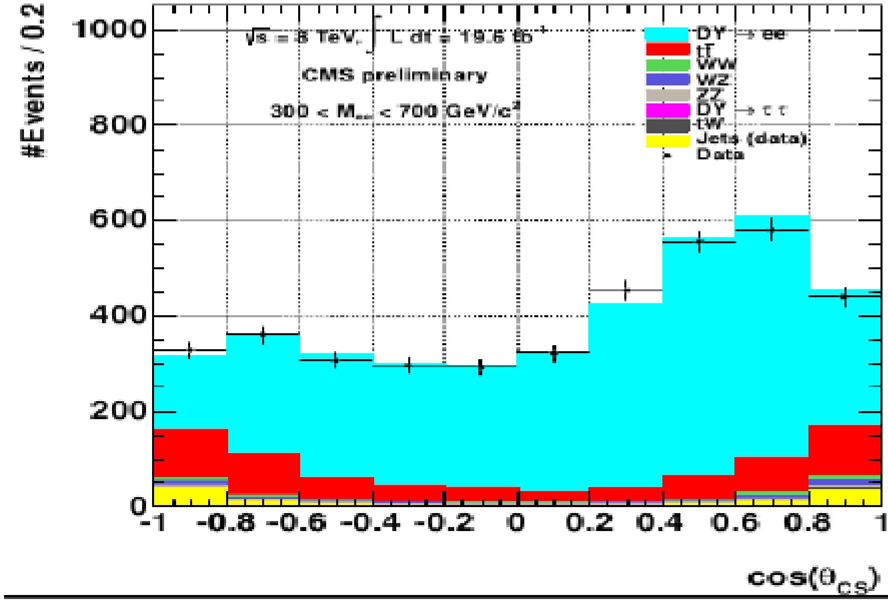
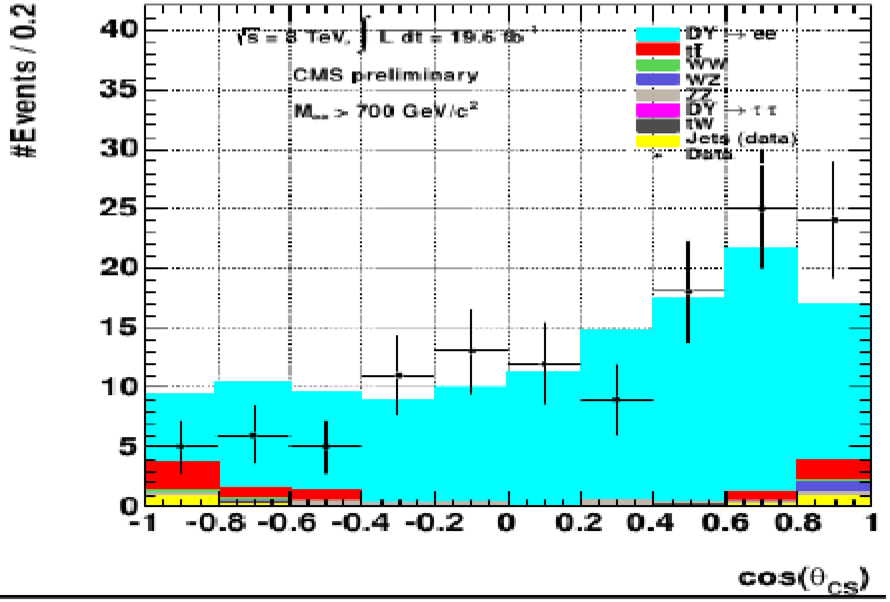
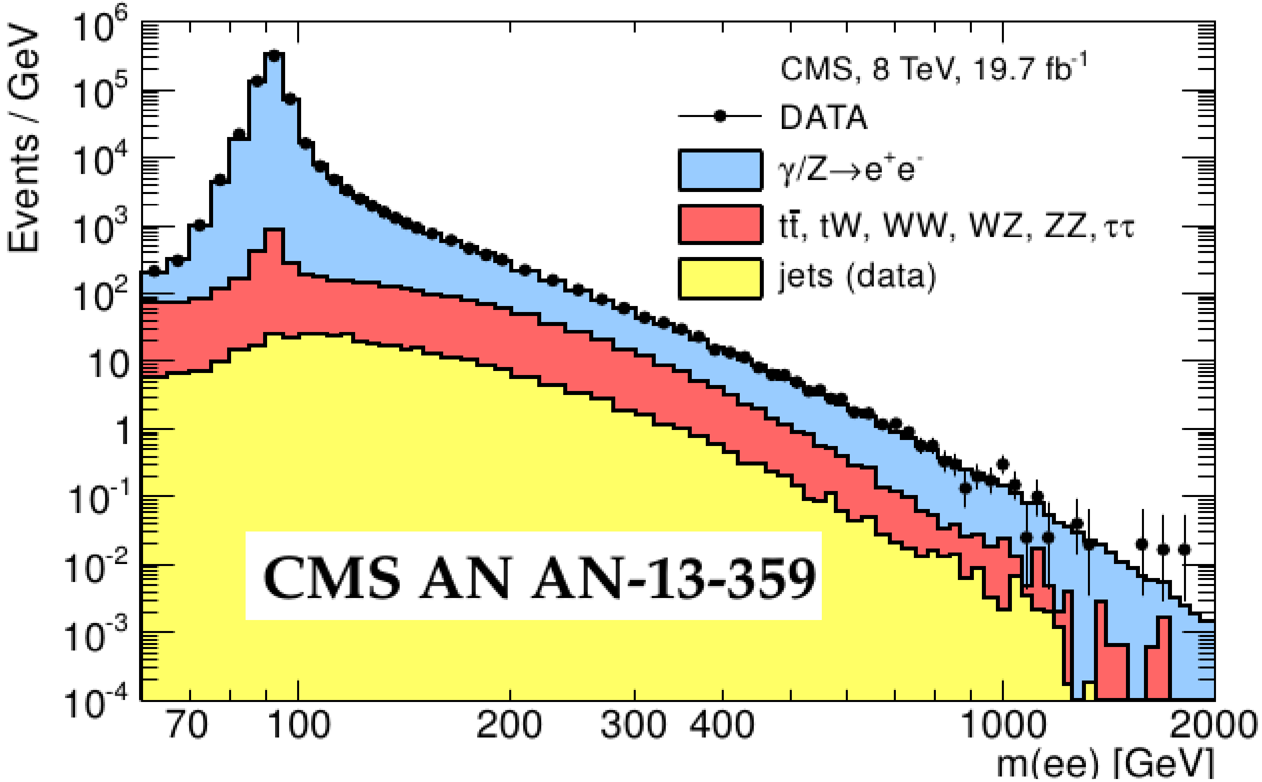
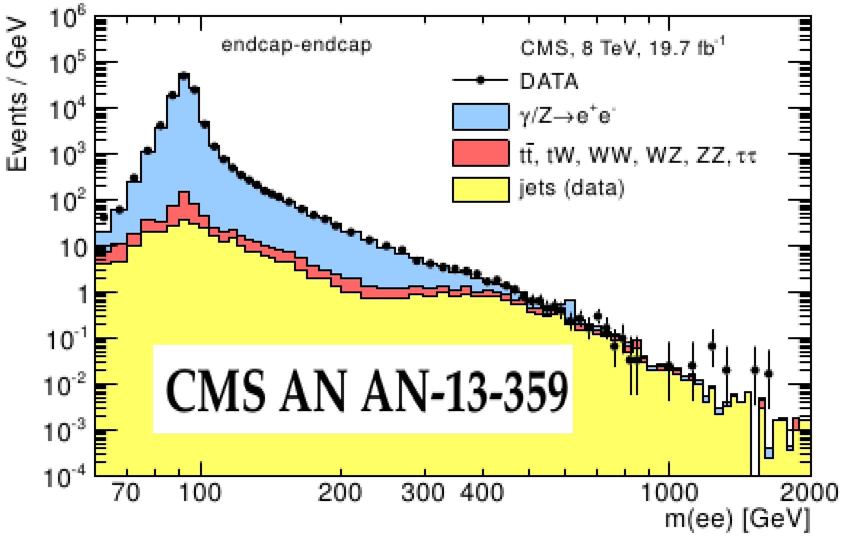
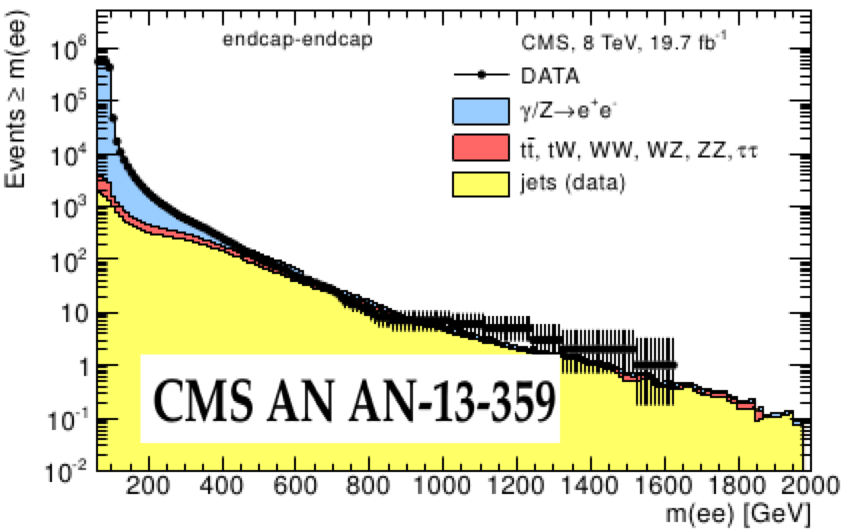




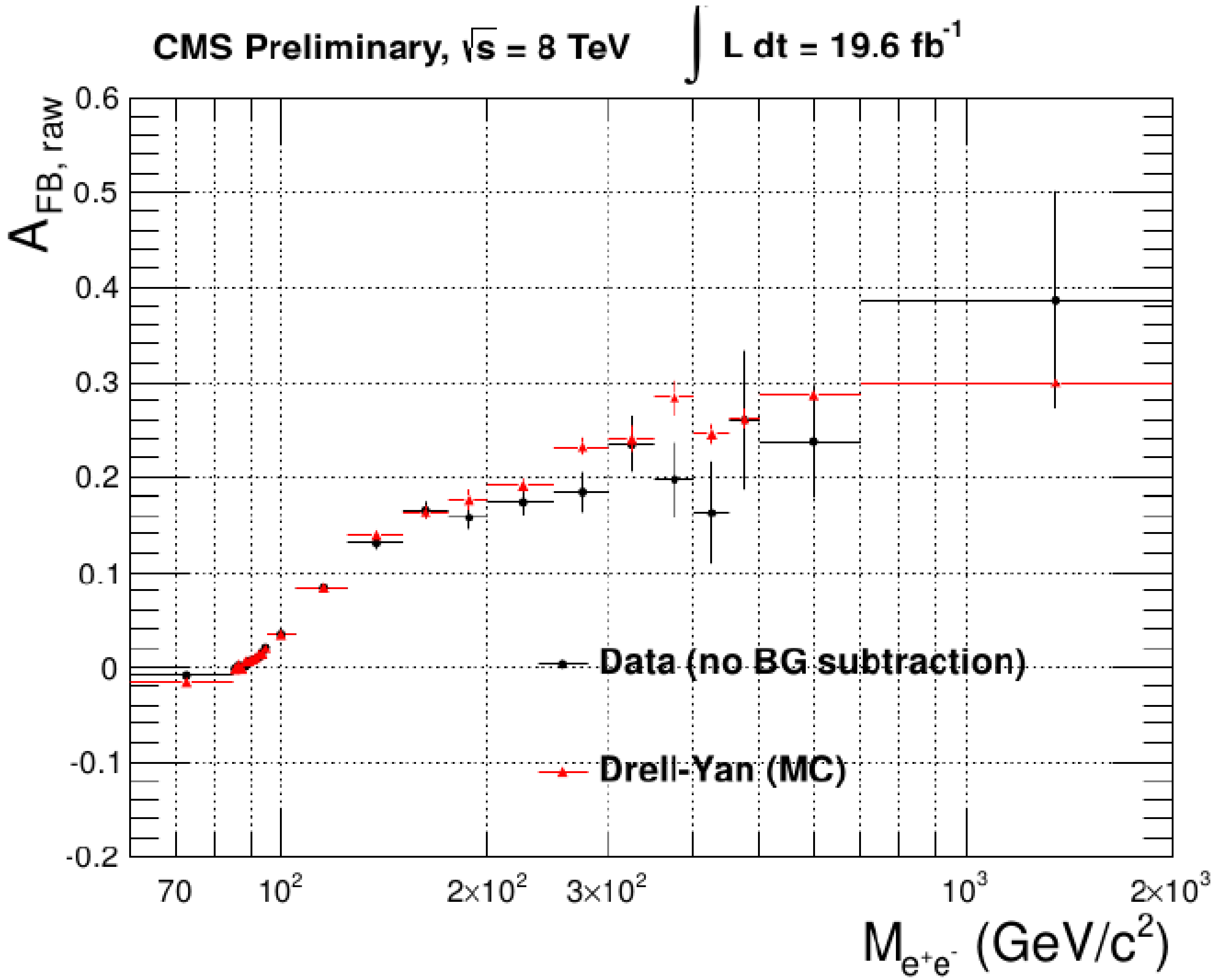
Inariant Mass Plots in Di-Electron Channel







Forward Backward asymmetry



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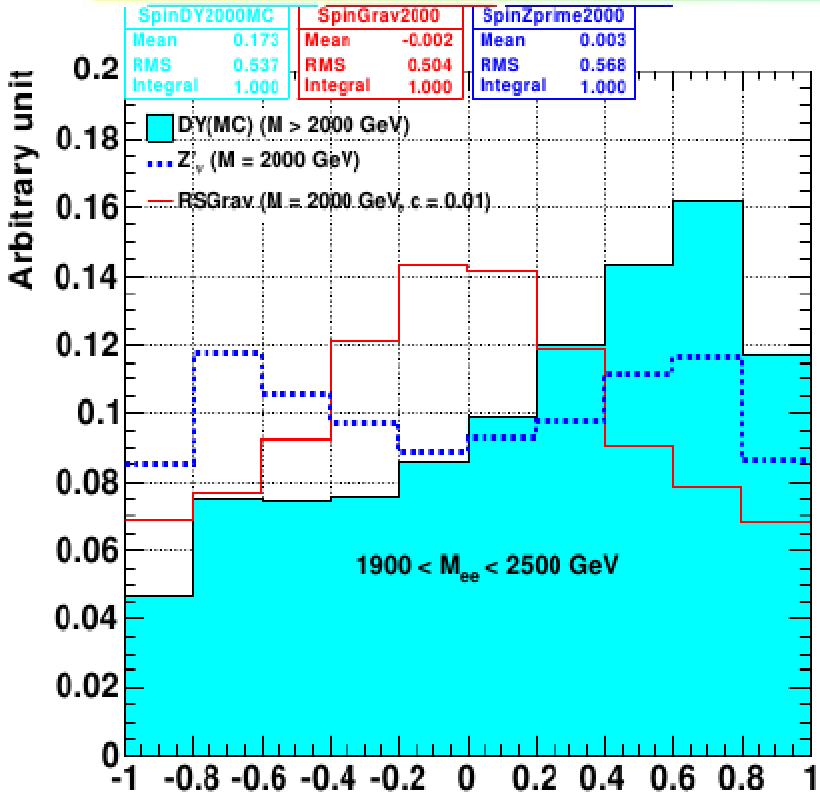
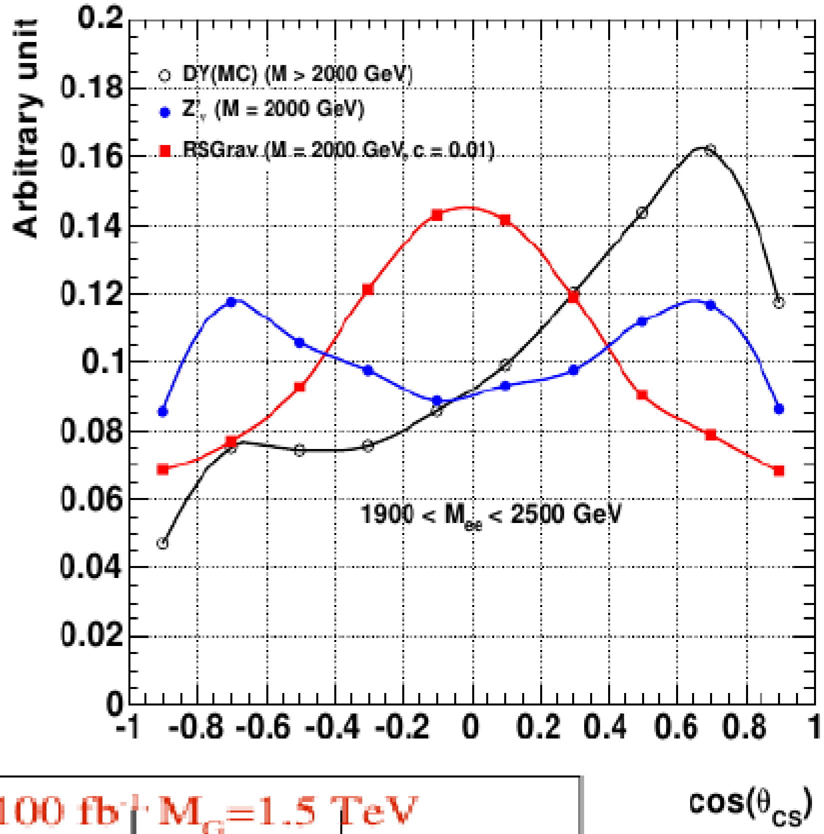
Collins Soper angle (for high mass DY > 2 TeV & Signals)





DY Mee > 2 TeV/c²

Z'ψ Mee = 2 TeV/c²

RS G Mee = 2 TeV/c²

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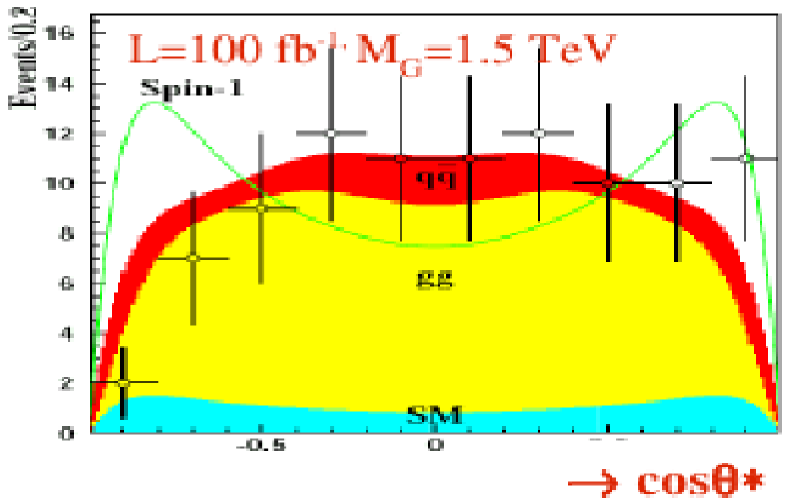

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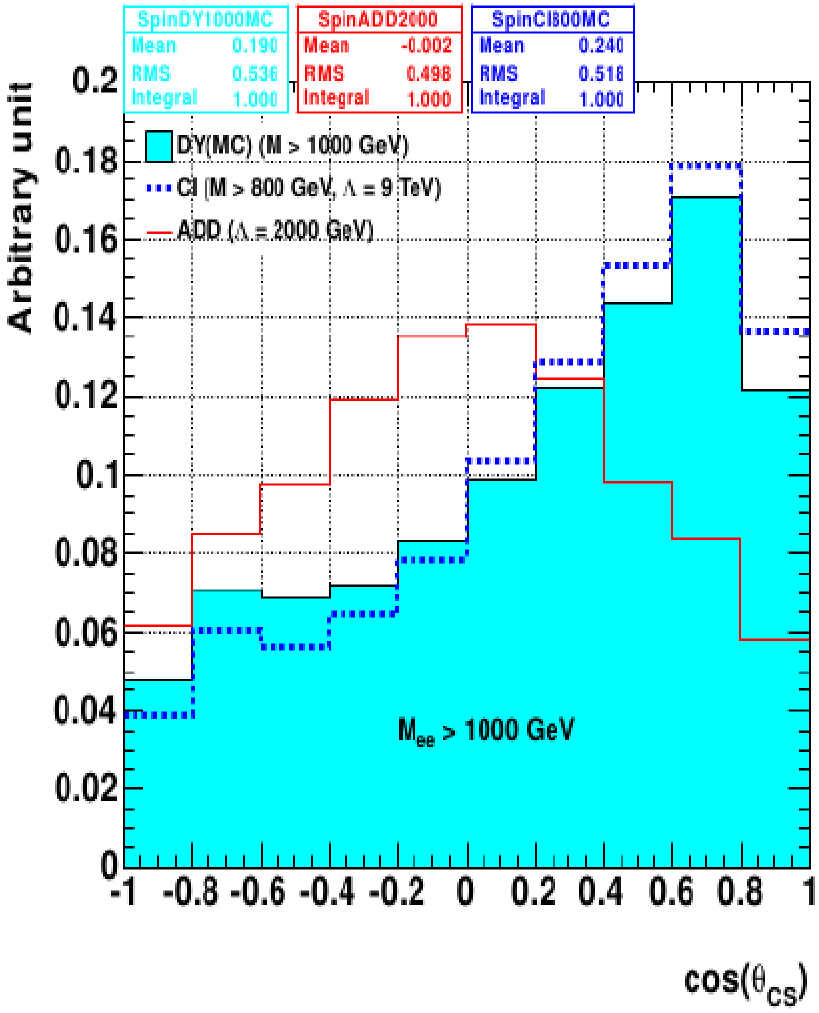
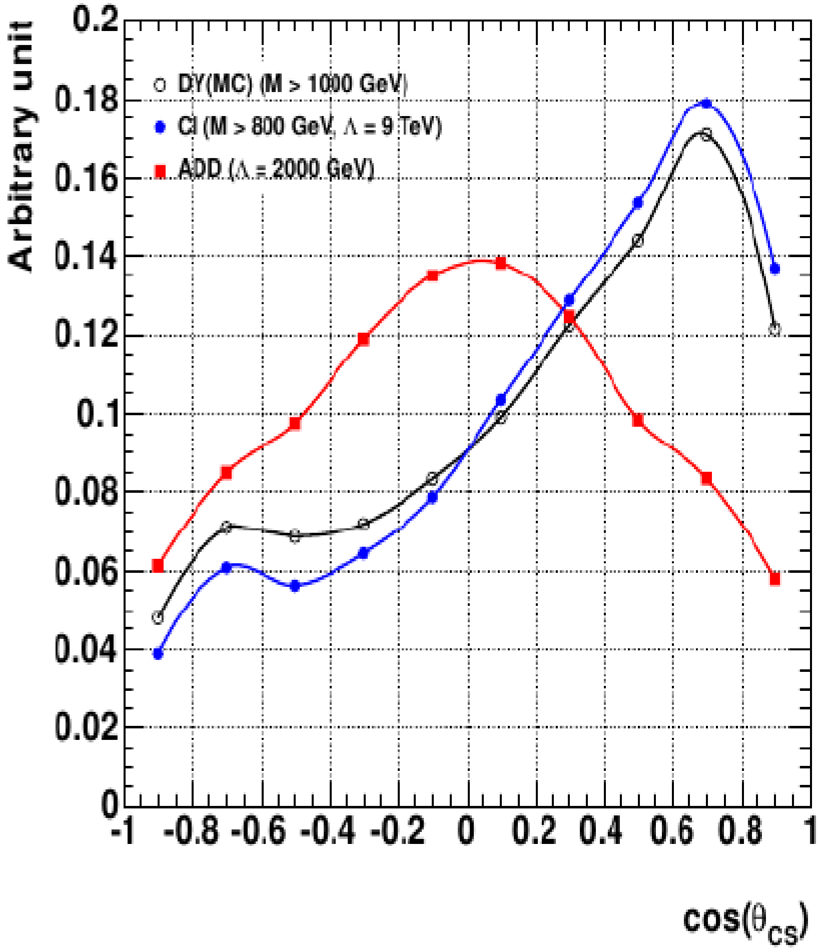
Collins Soper angle (for high mass DY > 2 TeV & Signals)





DY Mee > 1 TeV/c^2
CI Mee > 0.8 TeV/c^2
RS G = 2 TeV/c^2

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1D vs 2D RS Graviton (10 events)

the log likelihood ratio, Q, as:

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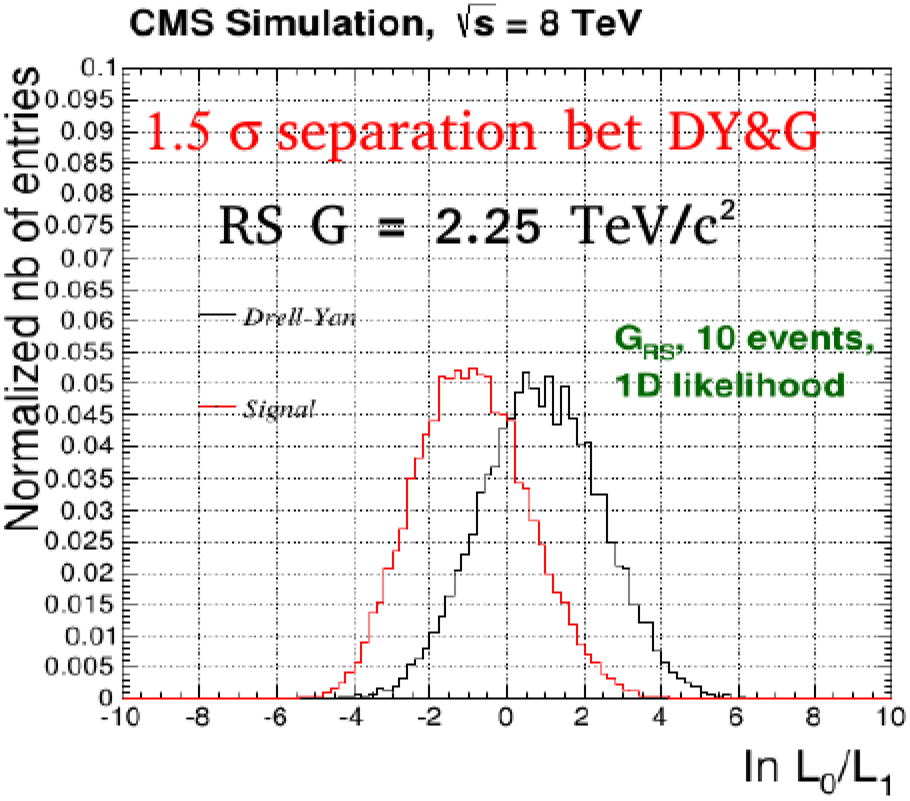
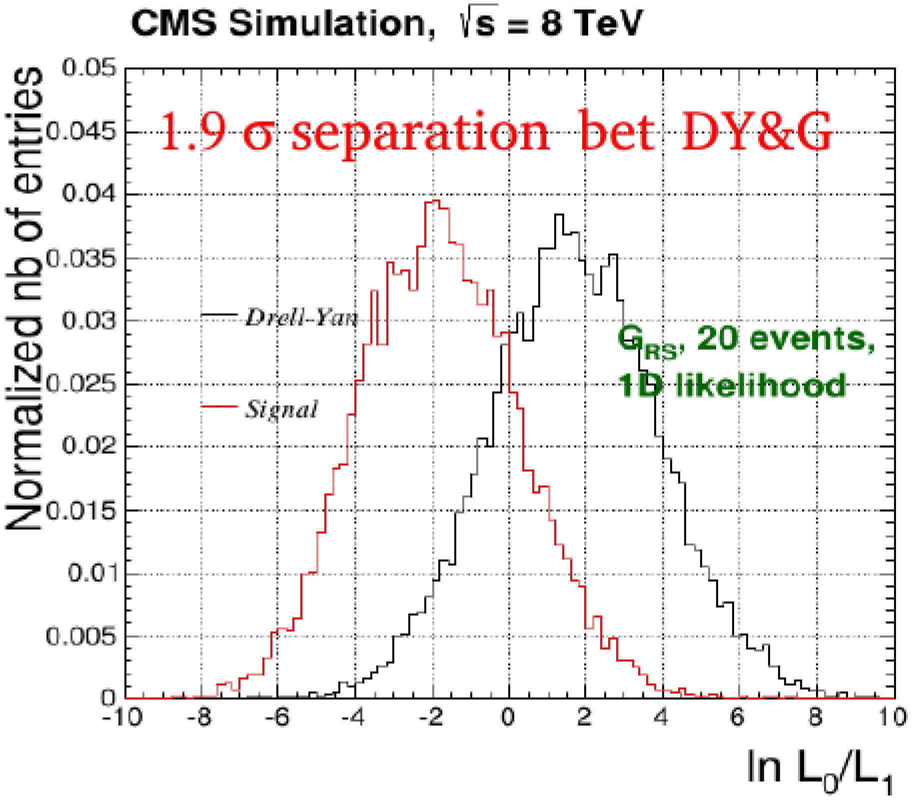
$$Q = ln\frac{\mathcal{L}_0}{\mathcal{L}_1} = ln\frac{\prod_{i=1}^{n} p_0(\vec{x_i})}{\prod_{i=1}^{n} p_1(\vec{x_i})}$$





In this analysis, the pdf $p_0(\vec{x})$ and $p_1(\vec{x})$ are binned and obtained from the Monte Carlo simulations. In order to avoid a possible bias due to the limited statistics, separate events are used to generate the pdf used for the pseudo-experiments generation and those used in the likelihood calculation.

1D vs 2D RS Graviton (20 events)

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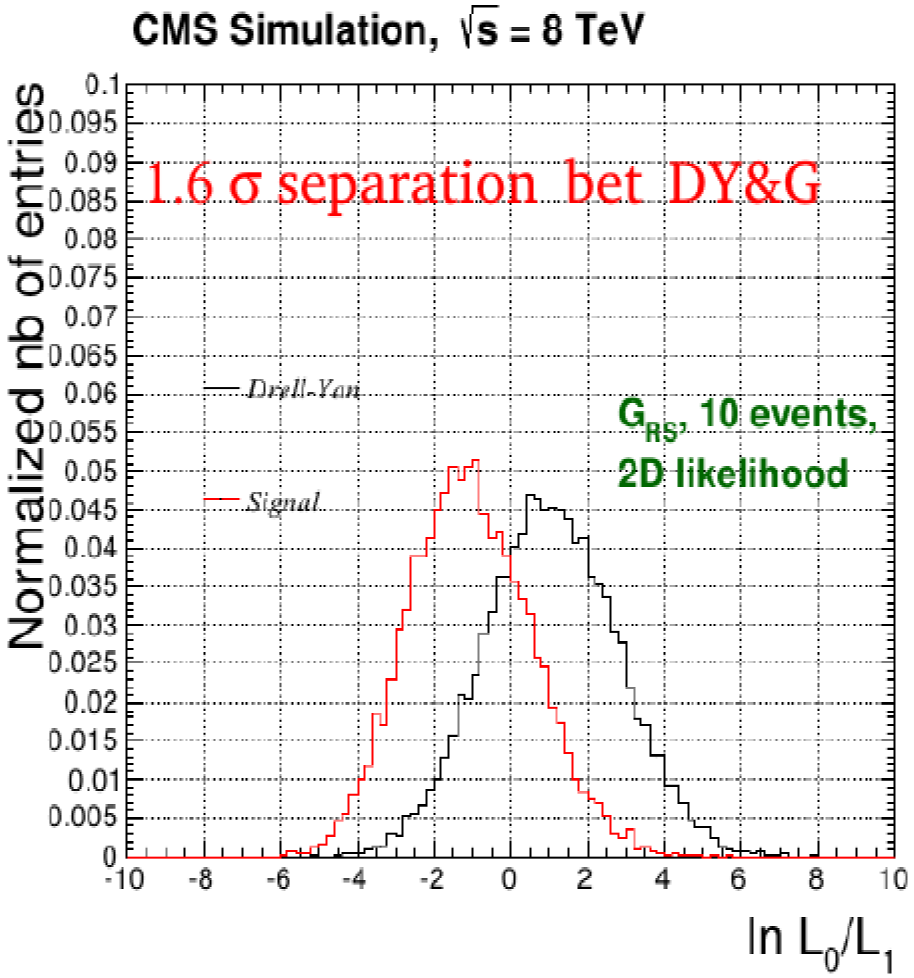

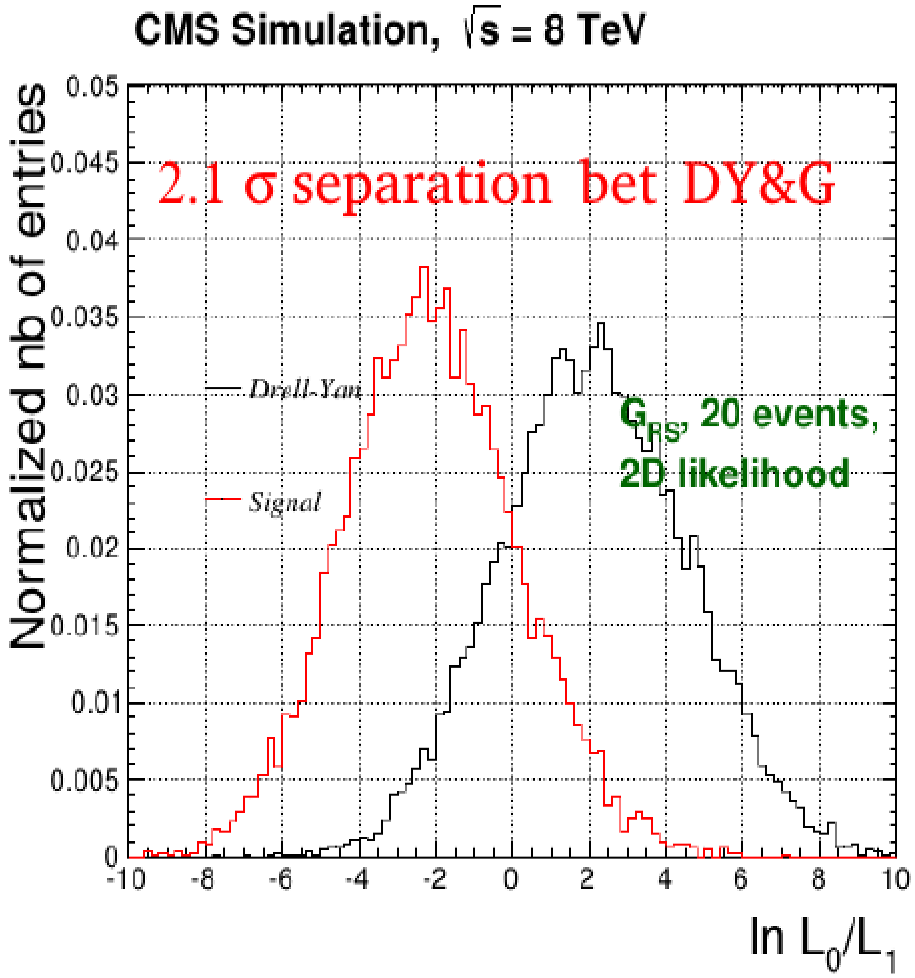

New Study

Suppose we have access at 1 TeV

Topological Likelihood

(1) the chosen set variables are only loosely correlated to each other.

(2) then we can develop a likelihood discriminant using chosen set of variables $\{x_i\}$:

(3) Likelihood shows good separation between signal and background

(4) can be applied to the selected events from data

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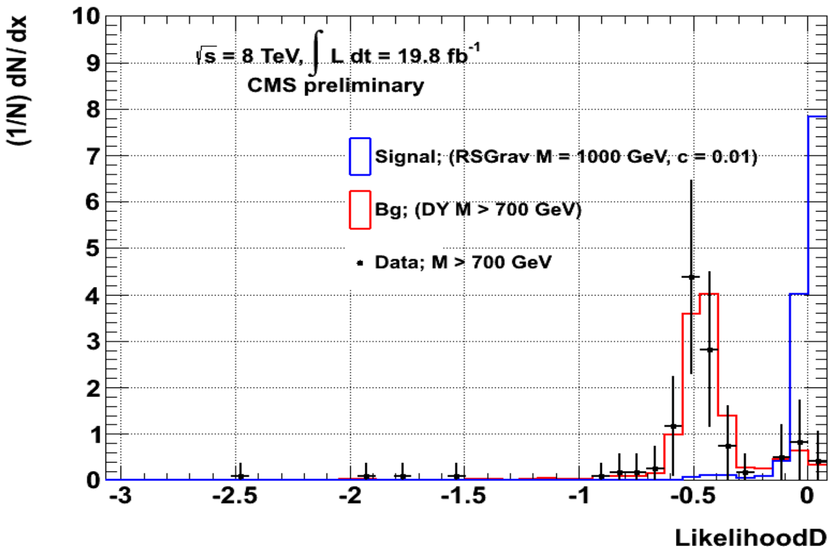
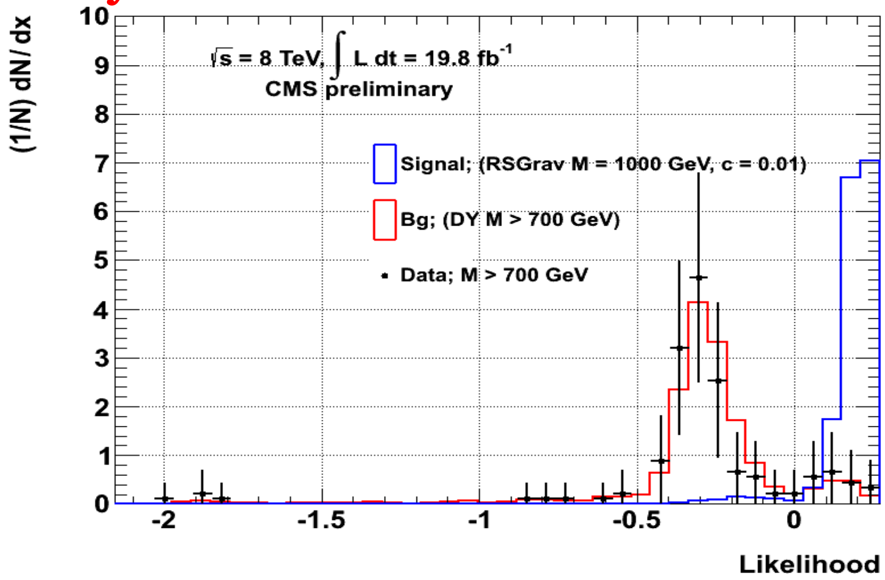
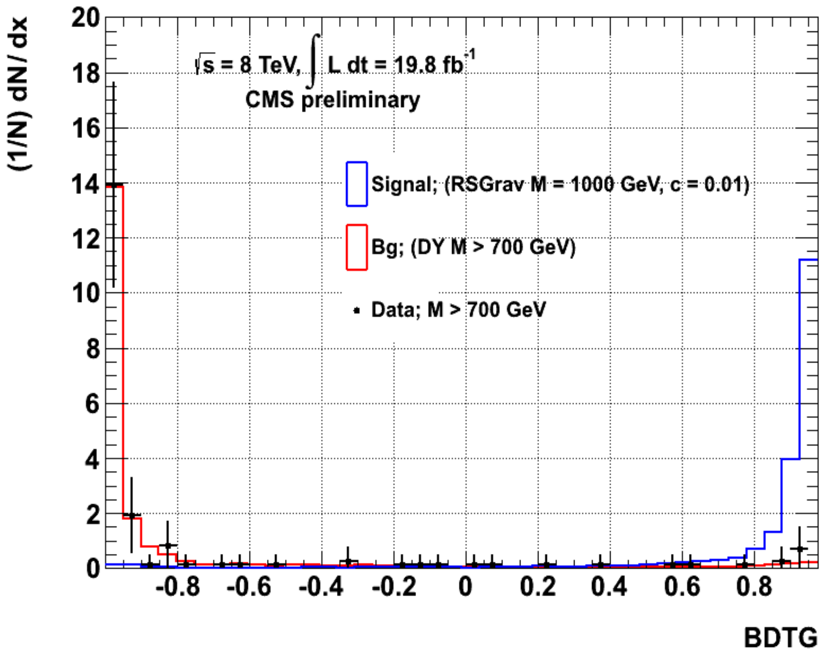
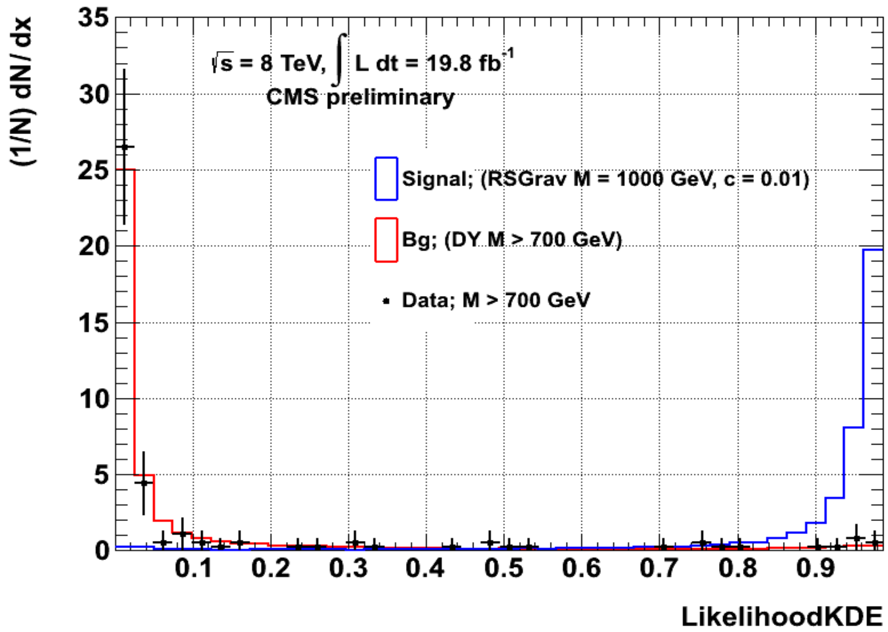
Classification for RSGrav at 1 TeV

New Study



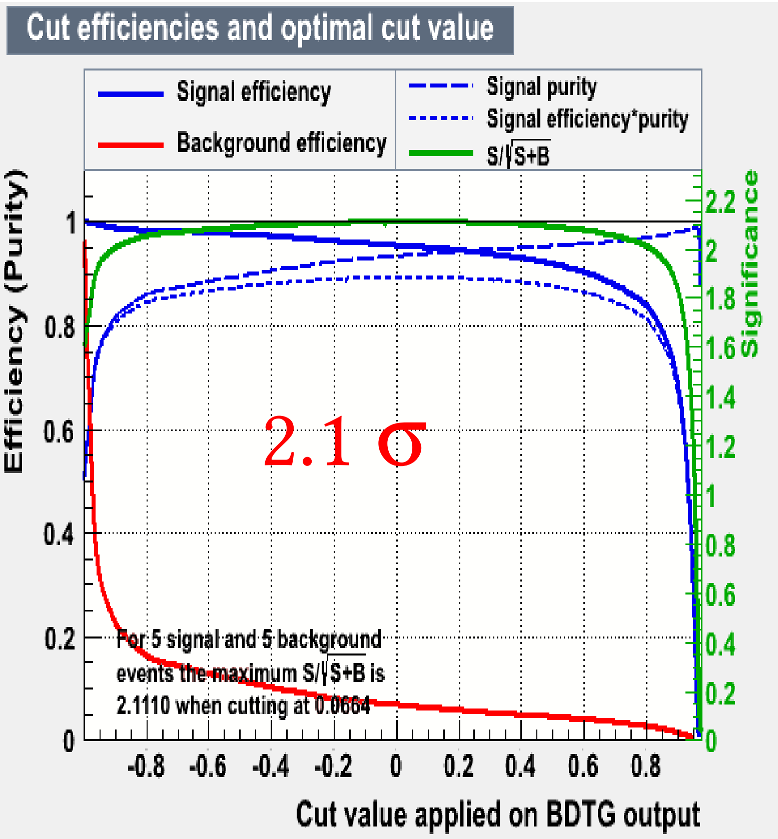


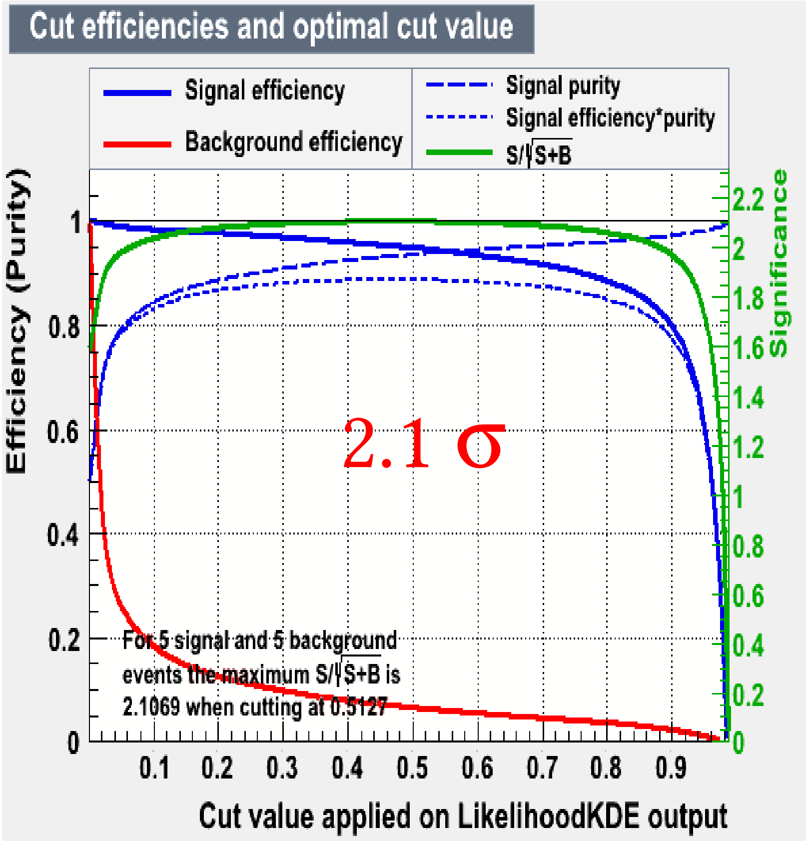




Significance for 5 events for G* at 1 TeV

---	Classifier	#signal	Optimal-cut	S/sqrt(S+B)	NSig	NBkg	EffSig	EffBkg
---	Likelihood:	5	0.0423	2.09854	4.789803	0.4197713	0.958	0.08395
---	LikelihoodD:	5	-0.1101	2.08826	4.784287	0.4645813	0.9569	0.09292
---	LikelihoodPCA:	5	0.7228	2.07049	4.79348	0.5663908	0.9587	0.1133
---	LikelihoodKDE:	5	0.5127	2.10694	4.742616	0.3241424	0.9485	0.06483
---	BDTG:	5	0.0664	2.11101	4.762839	0.3275761	0.9526	0.06552





Signal is G*

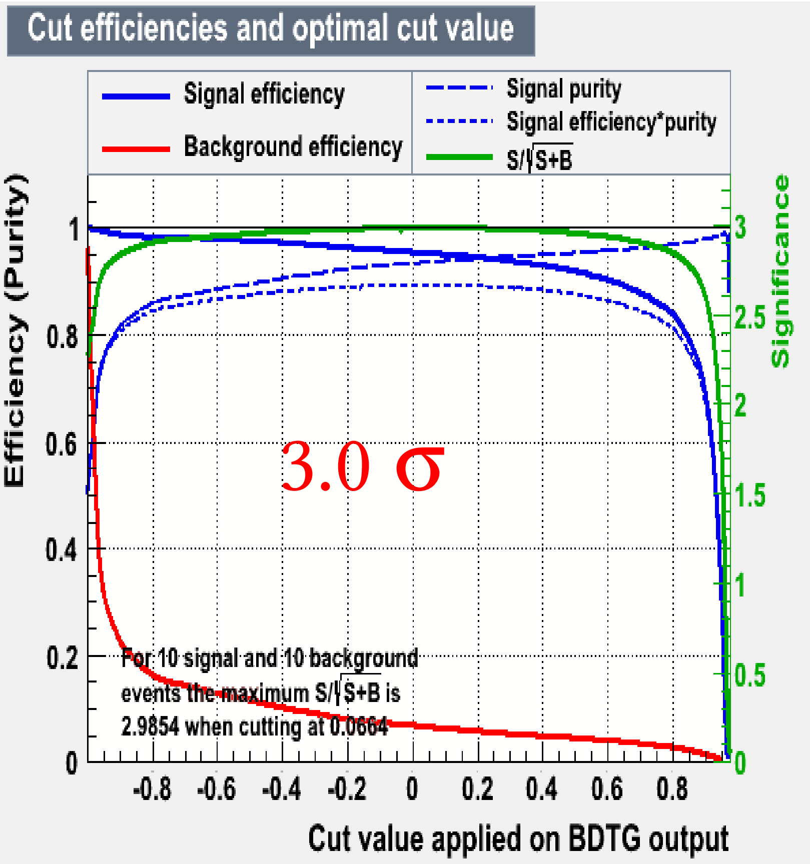
Background is DY(M>700 GeV)

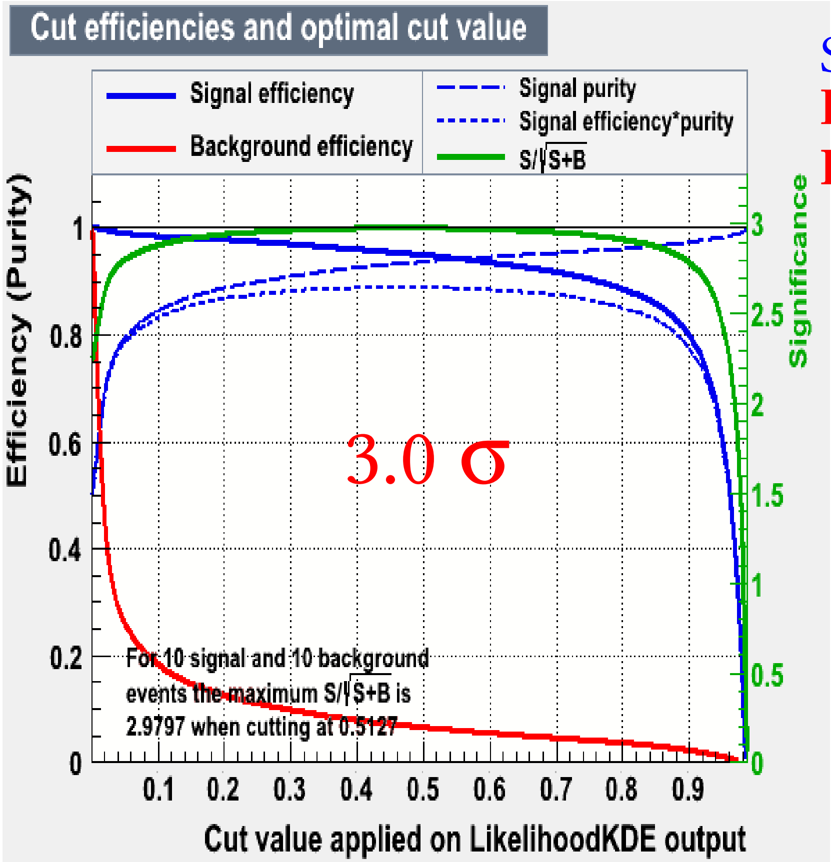
New Study

BUE

Significance for 10 events for G* at 1 TeV

Classifier	#signal	Optimal-cut	S/sqrt(S+B)	NSig	NBkg	EffSig	EffBkg
Likelihood:	10	0.0423	2.96778	9.579605	0.8395426	0.958	0.08395
LikelihoodD:	10	-0.1101	2.95324	9.568575	0.9291625	0.9569	0.09292
LikelihoodPCA:	10	0.7228	2.92812	9.586959	1.132782	0.9587	0.1133
LikelihoodKDE:	10	0.5127	2.97967	9.485231	0.6482849	0.9485	0.06483
BDTG:	10	0.0664	2.98541	9.525677	0.6551523	0.9526	0.06552





Signal is G*

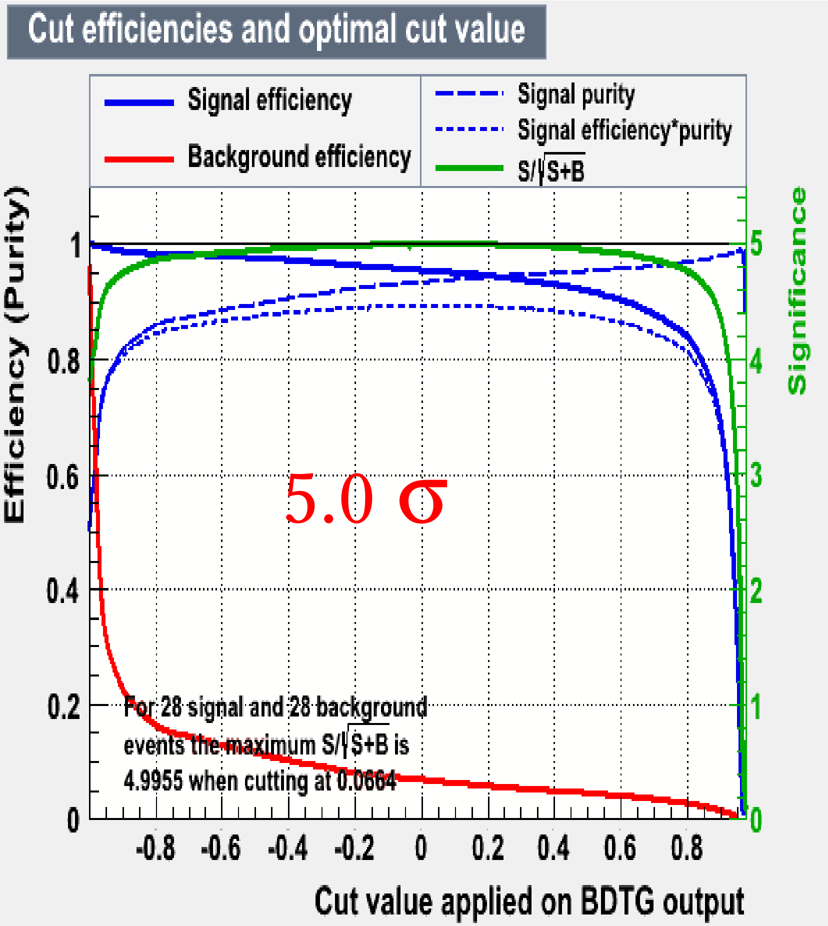
Background is DY(M>700 GeV)

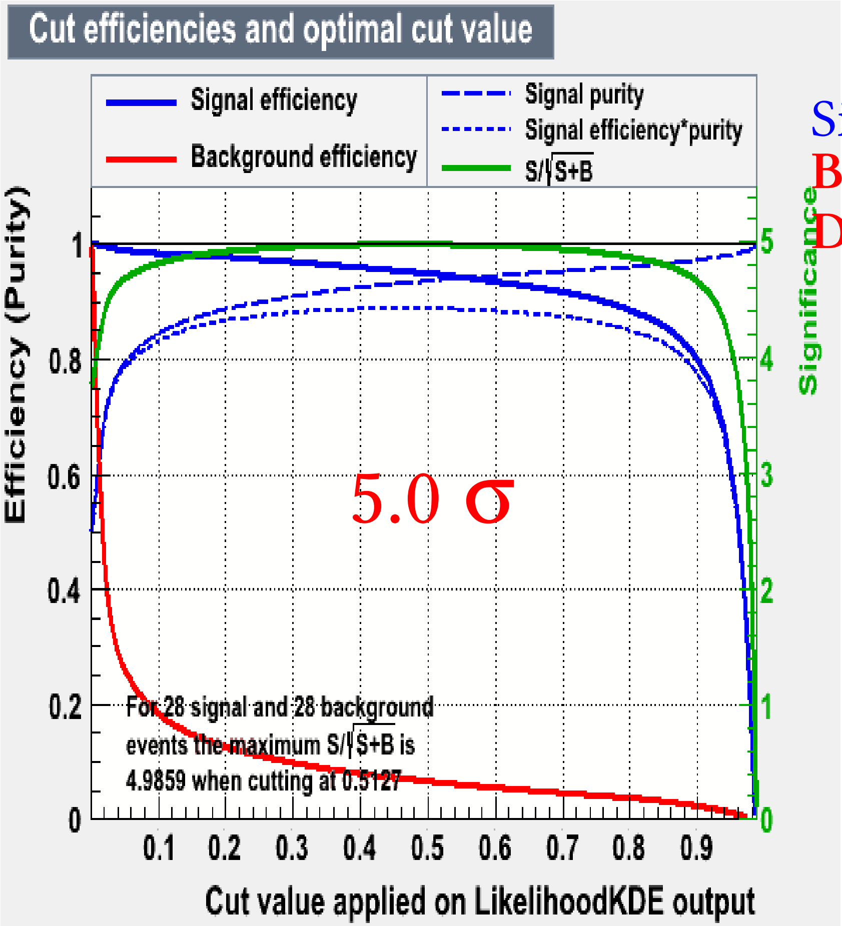
New Study

Significance for 28 events for G* at 1 TeV

BUE

---	Classifier	#signal	Optimal-cut	S/sqrt(S+B)	NSig	NBkg	EffSig	EffBkg
---	Likelihood:	28	0.0423	4.96604	26.82289	2.350719	0.958	0.08395
---	LikelihoodD:	28	-0.1101	4.94172	26.79201	2.601655	0.9569	0.09292
---	LikelihoodPCA:	28	0.7228	4.89968	26.84349	3.171789	0.9587	0.1133
---	LikelihoodKDE:	28	0.5127	4.98594	26.55865	1.815198	0.9485	0.06483
---	BDTG:	28	0.0664	4.99555	26.6719	1.834426	0.9526	0.06552





Signal is G*
Background is DY(M>700 GeV)

New Study

Conclusion

(1) The angular distributions [cos(θ^*)] have been studied in the framework of HEEP selection (v4.1) using MC DY(M > 2000 GeV), RSgrav(M = 2000 GeV) and Z' psi(M = 2000 GeV), using CMSSW_5_3_X and full 2012 data

(2) It was found that the CS polar angles cos(θ_{cs}) **is** good variable to distinguish between the BSM bosons [G (ADD or RS) and Z'] and the DY b.g. Process.

(3) Good agreements are seen between data and DY MC(M > 120 GeV).

(4) we can reach **2σ** separation bet G (M=2.25TeV) & DY at high mass with 20 events.

(5) In the preparation for 2015 data taking, with the use of topological likelihood, with the hypothesis of having excess of data at 1 TeV/c^2

(a) 5 events allows 2.1 σ discrimination betw.G* & DY
(b) to reach 5.0 σ discrimination 28 events are needed

Thanks to FP7 Project

Back Up

Backup

Terminologies

[1] **In this study I used MVA Version 4.2.0, Sep 19, 2013**

[2] **Likelihood**

The likelihood ratio $y_{\mathcal{L}}(i)$ for event i is defined by

$$y_{\mathcal{L}}(i) = \frac{\mathcal{L}_S(i)}{\mathcal{L}_S(i) + \mathcal{L}_B(i)} ,$$

where

$$\mathcal{L}_{S(B)}(i) = \prod_{k=1}^{n_{\text{var}}} p_{S(B),k}(x_k(i)) ,$$

[3] **LikelihoodD**

the "D" extension indicates decorrelated input variables (see option strings)

[4] Likelihood KDE

3.1 Kernel Density Estimator (KDE)

KDE is a non-parametric technique to estimate a probability density function $p(\boldsymbol{x})$ defined on $\mathbb{R}^d$ from its i.i.d. samples $\{\boldsymbol{x}_i\}_{i=1}^n$. For the Gaussian kernel, KDE is expressed as

$$\widehat{p}(\boldsymbol{x}) = \frac{1}{n(2\pi\sigma^2)^{d/2}} \sum_{i=1}^{n} \exp\left(-\frac{\|\boldsymbol{x} - \boldsymbol{x}_i\|^2}{2\sigma^2}\right).$$

[5] Likelihood PCA (Principle Component Analysis)

2.2 Maximum Likelihood PCA (MLPCA)

MLPCA estimates the model that maximizes the likelihood of estimating the true principal components and projection directions given the measured variables, or equivalently maximizing the probability density function of the measurements given the noise-free principal components, projection directions, and the true rank of the data matrix "$\tilde{\mathrm{p}}$", as

$$\left\{\hat{\boldsymbol{\alpha}}, \hat{\mathbf{Z}}\right\}_{\mathrm{MLPCA}} = \arg\max_{\tilde{\boldsymbol{\alpha}}, \tilde{\mathbf{Z}}} L\left(\tilde{\boldsymbol{\alpha}}, \tilde{\mathbf{Z}}, \tilde{\mathbf{p}}; \mathbf{X}\right) = \arg\max_{\hat{\boldsymbol{\alpha}}, \tilde{\mathbf{Z}}} P\left(\mathbf{X} \mid \tilde{\boldsymbol{\alpha}}, \tilde{\mathbf{Z}}, \tilde{\mathrm{p}}\right) \quad (7)$$

[7] Boosted decision tree Gradient (BDTG)

- Output(or response): a random variable y
- Input(or explanatory): a set of random variables $\mathbf{x} = \{x_1, \ldots, x_n\}$
- Goal: using a training sample $\{y_i, \mathbf{x}_i\}_1^N$ of known $(y, \mathbf{x})$ values to obtain an estimate $\hat{F}(\mathbf{x})$ of the function $F^*(\mathbf{x})$ mapping $\mathbf{x}$ to y
- Minimizing the expected value of some specified loss function $L(y, F(\mathbf{x}))$:

$$F^* = \arg\min_{F} E_{y,\mathbf{x}} L(y, F(\mathbf{x})). \quad (1)$$

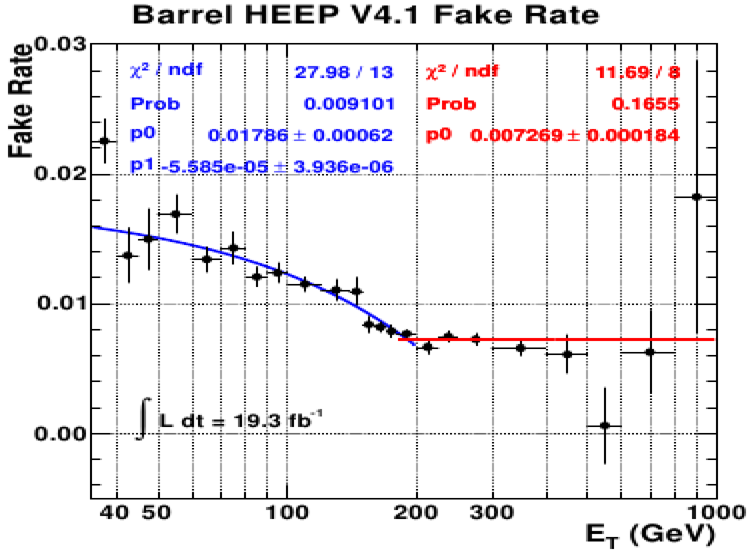
- Take a non-parametric approach
- Apply numerical optimization in function space
- Consider $\mathbf{F}(\mathbf{x})$ evaluated at each point $\mathbf{x}$ to a parameter and seek to minimize $\Phi(F) = E_{y,\mathbf{x}} L(y, F(\mathbf{x})) = E_{\mathbf{x}}[E_y(L(y, F(\mathbf{x})))|\mathbf{x}]$ at each individual $\mathbf{x}$, directly with respect to $F(\mathbf{x})$
- Numerical optimization paradigm:

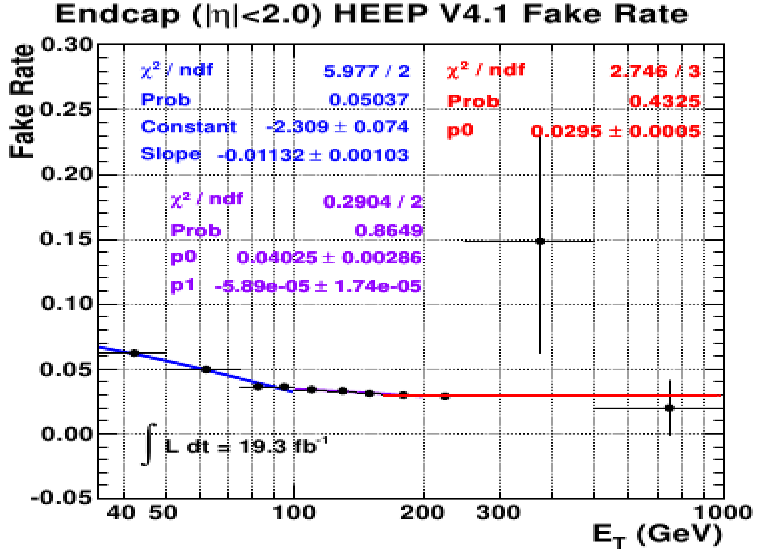
$$F^*(\mathbf{x}) = \sum_{m=0}^{M} f_m(\mathbf{x}),$$

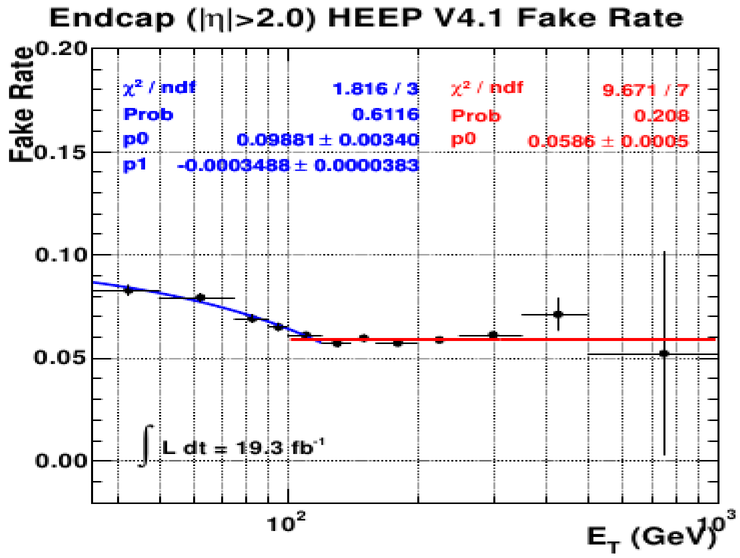
where $f_0(\mathbf{x})$ is an initial guess, and $\{f_m(\mathbf{x})\}_1^M$ are incremental functions (steps or boosts) defined by the optimization method

variable	barrel	endcap
$\sigma_{i\eta i\eta}$	<0.013	<0.034
H/E	<0.15	<0.10
nr. missing hits	$<= 1$	$<= 1$
$\lvert dxy \rvert$	< 0.02	< 0.05

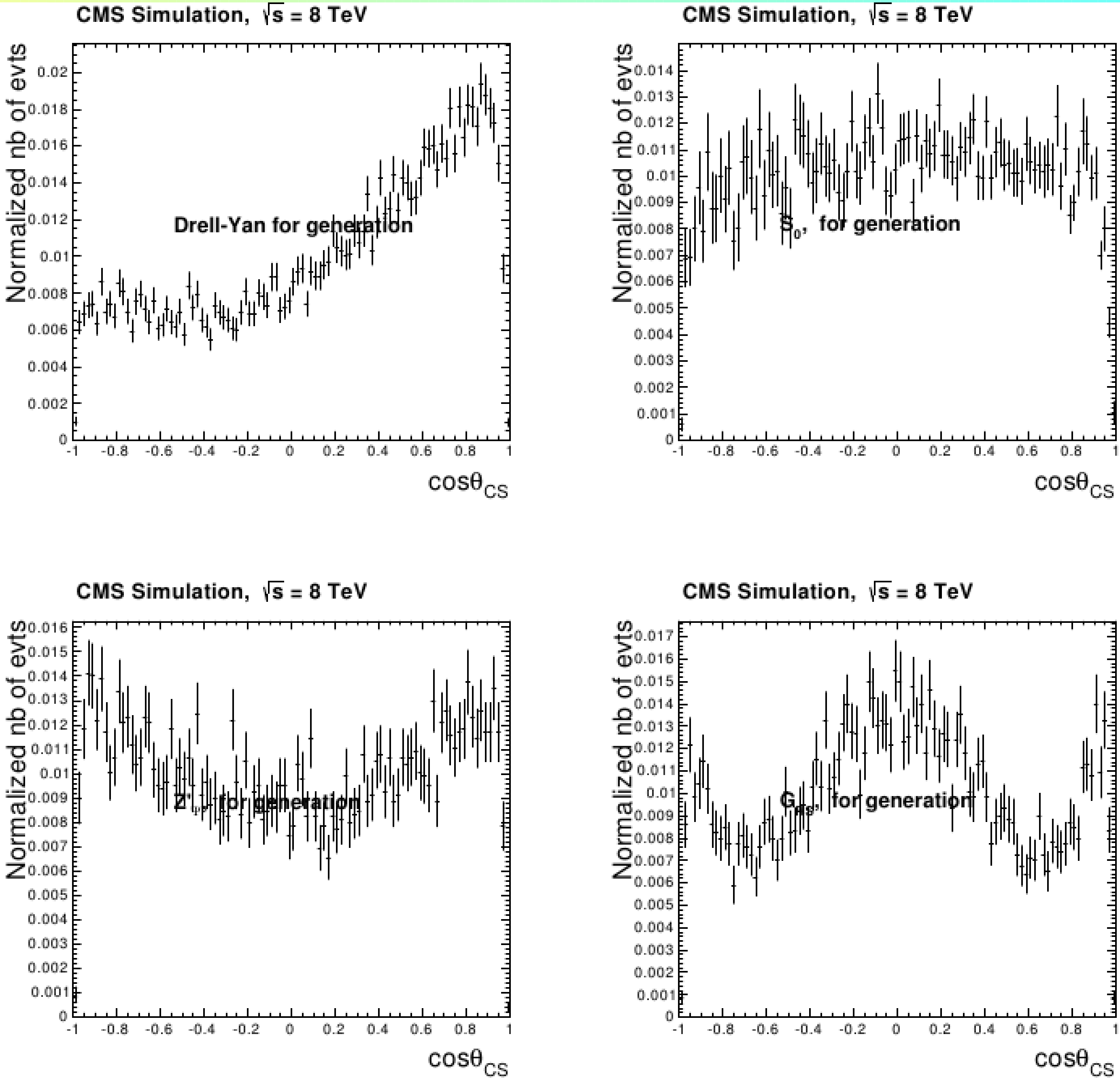
Table 13: The selection requirements for the starting point of the fake rate calculation.







Pdf in 1D analysis



Pdf in 2D analysis

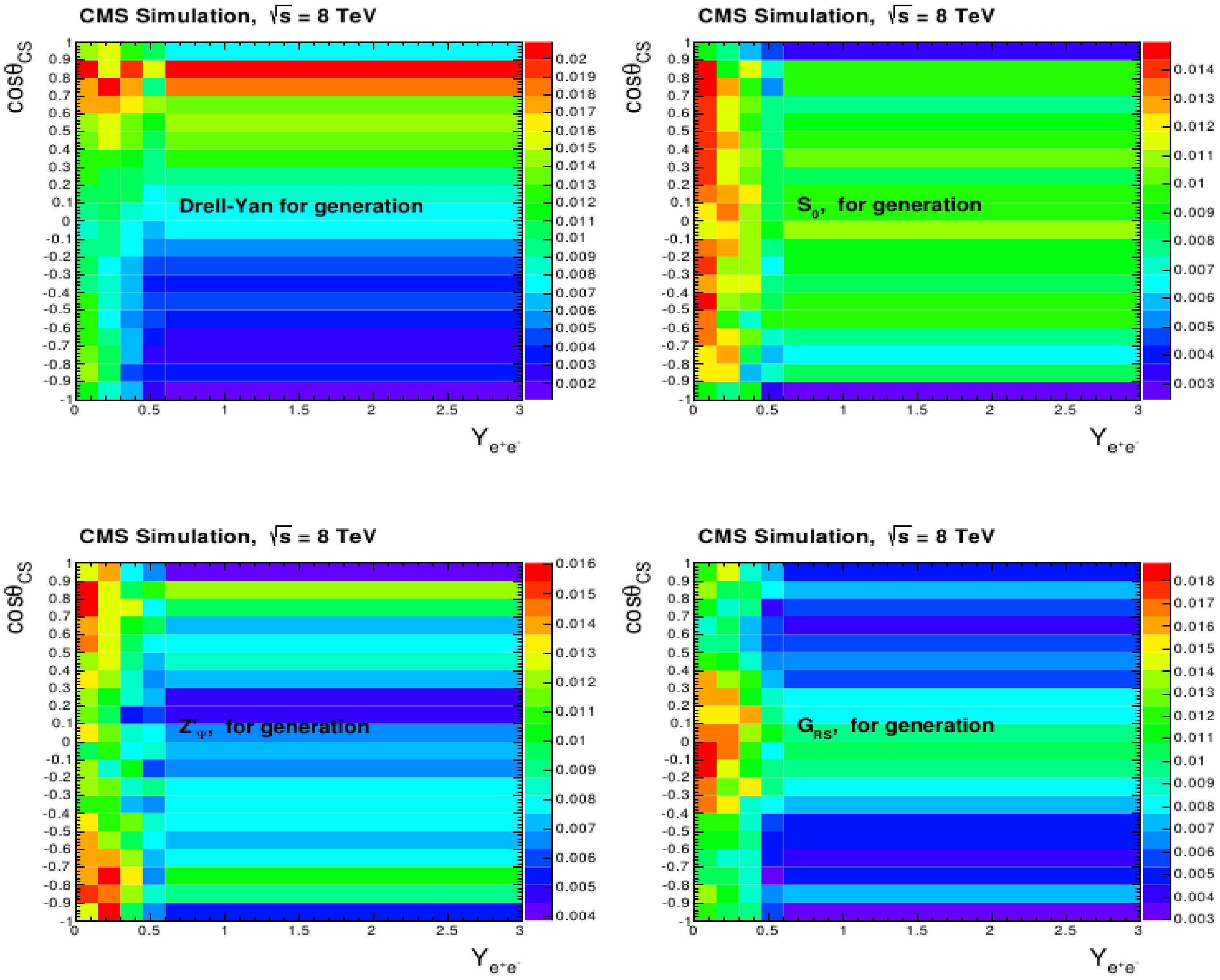


Figure 14: The normalized distributions of $(\cos\theta_{CS}, |y_{e^+e^-}|)$ defining the pdf in the 2D analysis for background (top left) and three signal samples, namely an isotropic model (top right), Z'_{Ψ} (bottom left), a Randall-Sundrum graviton (bottom right).

Signal sample, nb of evts, method	Exp. separation (in σ), (H_0 true)	Exp. separation (in σ) (H_1 true)
Spin 0, 10evts, 1D	1.0	1.3
Spin 0, 10evts, 2D	1.1	1.4
Spin 0, 20evts, 1D	1.4	1.6
Spin 0, 20evts, 2D	1.6	1.9
RSGrav, 10evts, 1D	1.2	1.5
RSGrav, 10evts, 2D	1.3	1.6
RSGrav, 20evts, 1D	1.6	1.9
RSGrav, 20evts, 2D	1.8	2.1
Z' Psi, 10evts, 1D	0.8	1.1
Z' Psi, 10evts, 2D	1	1.3
Z' Psi, 20evts, 1D	1.1	1.5
Z' Psi, 20evts, 2D	1.5	1.8

Table 4: Expected separation (in σ) obtained using the angular information of dielectron pairs between the Drell-Yan model and different models of new physics in case the background hypothesis (first column) or the signal hypothesis (second column) is true for different number of events and likelihood functions (1D or 2D).