Helicity determination in HEEP event using 2012 data

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CMS Egypt meeting

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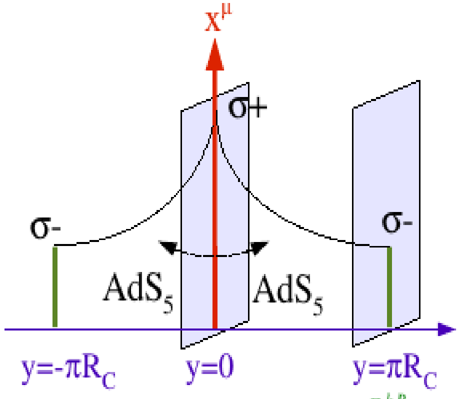
Models in Particle Physics

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}:

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

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:

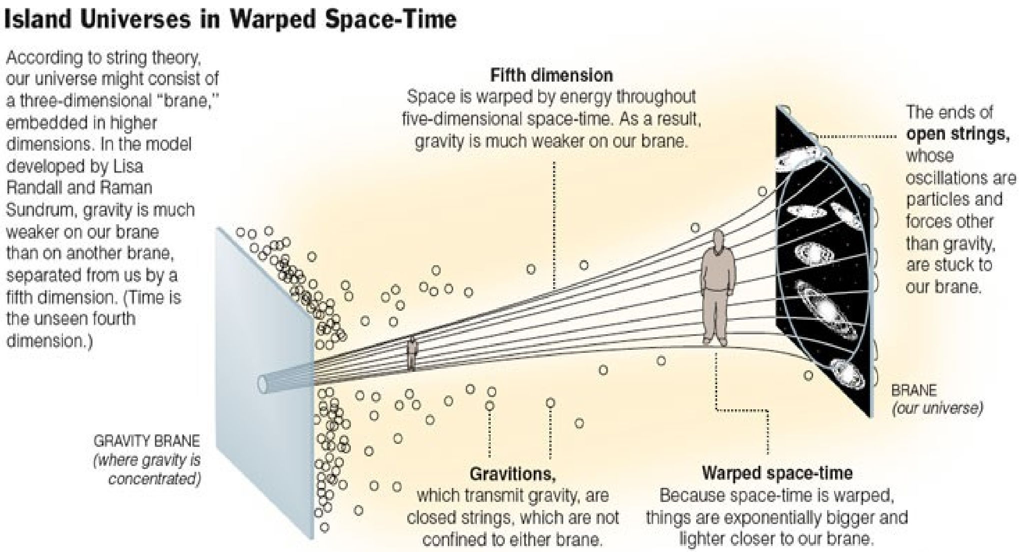
$k < M_D$ ($k <= 0.1 M_D$)

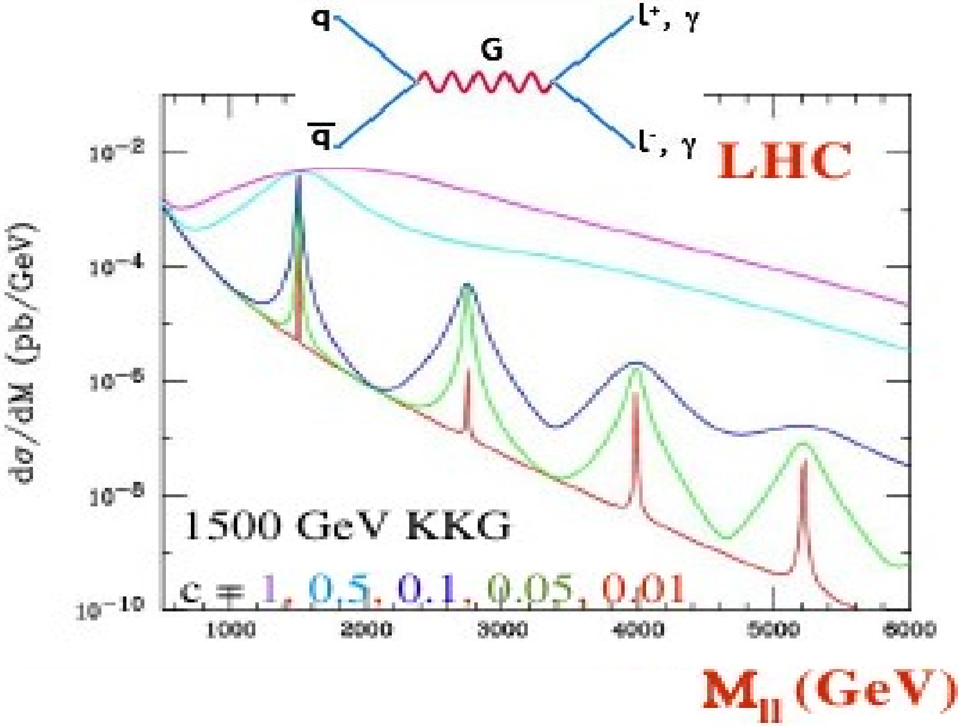
$k < 0.1 M_{Pl}$

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:

$$E_6 \to SO(10) \times U(1)_\psi \to SU(5) \times U(1)_\chi \times U(1)_\psi$$

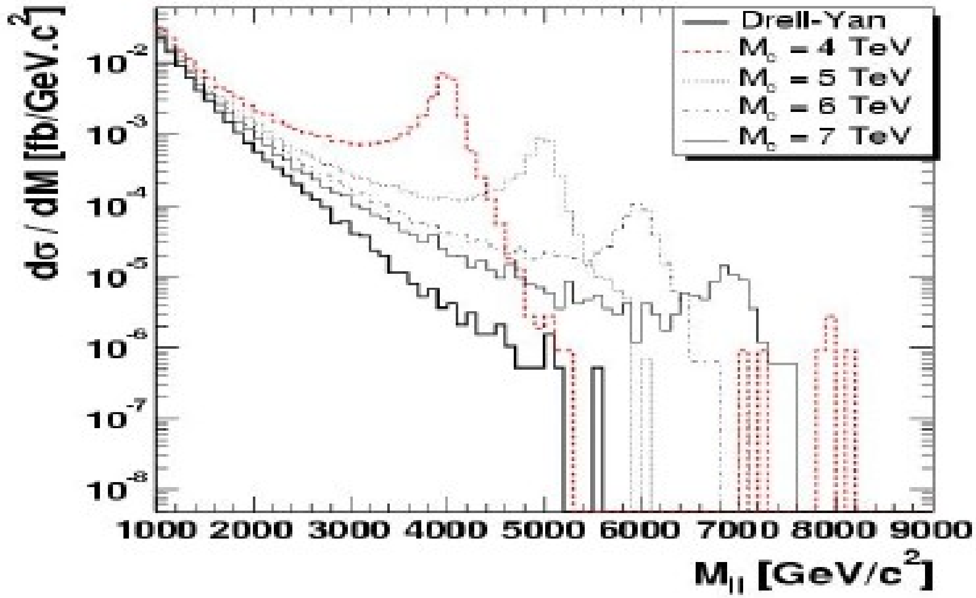
$$\to SU(3)_C \times SU(2)_L \times U(1)_Y \times U(1)' \,, \qquad (2.2)$$

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

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

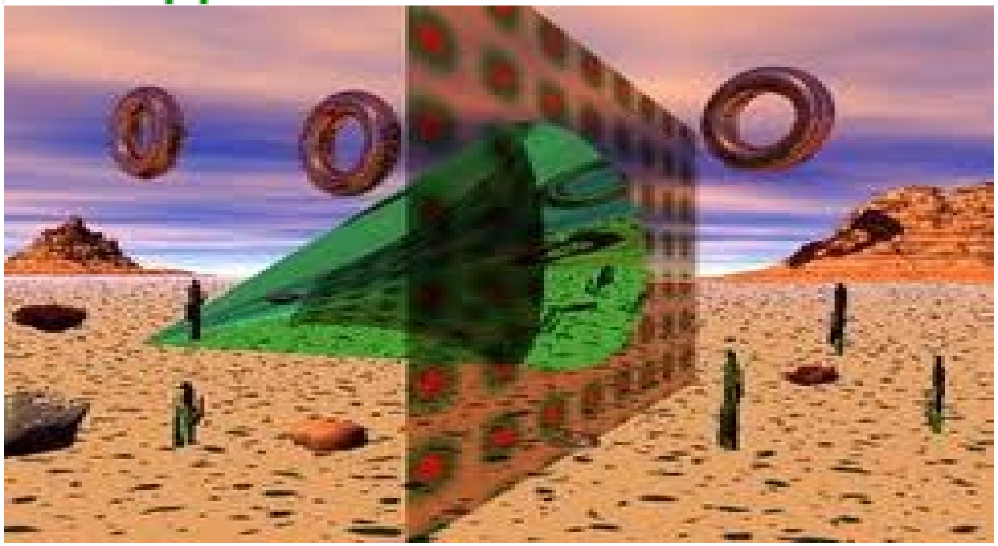
where θ, for E_6, is a free parameter [17]; if $\theta = 0$, one extra gauge boson Z'_χ exists from $SO(10)$, while for $\theta = \pi/2$ only Z'_ψ from E_6 is obtained. Finally, $U(1)_\eta$ is a particular combination of $U(1)_\chi$ and $U(1)_\psi$, i.e., $\theta = 2\pi - \tan^{-1}\sqrt{5/3}$, which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

[Rizzo, PRD61(2000) 055005)]



ADD: Arkadi-Hamed, Dimopoulos and Dvali

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



Gauss law: relates M_D to M_{Pl} :

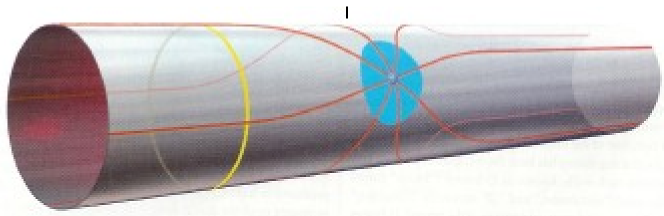
$$r \ll R_C \quad \rightarrow V_{4+\delta}(r) = -\frac{1}{M_D^{2+\delta}} \frac{m}{r^{\delta+1}}$$

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

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

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

Dimension



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

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

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

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

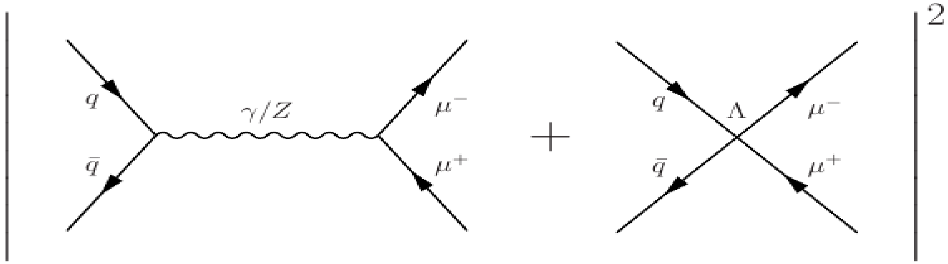
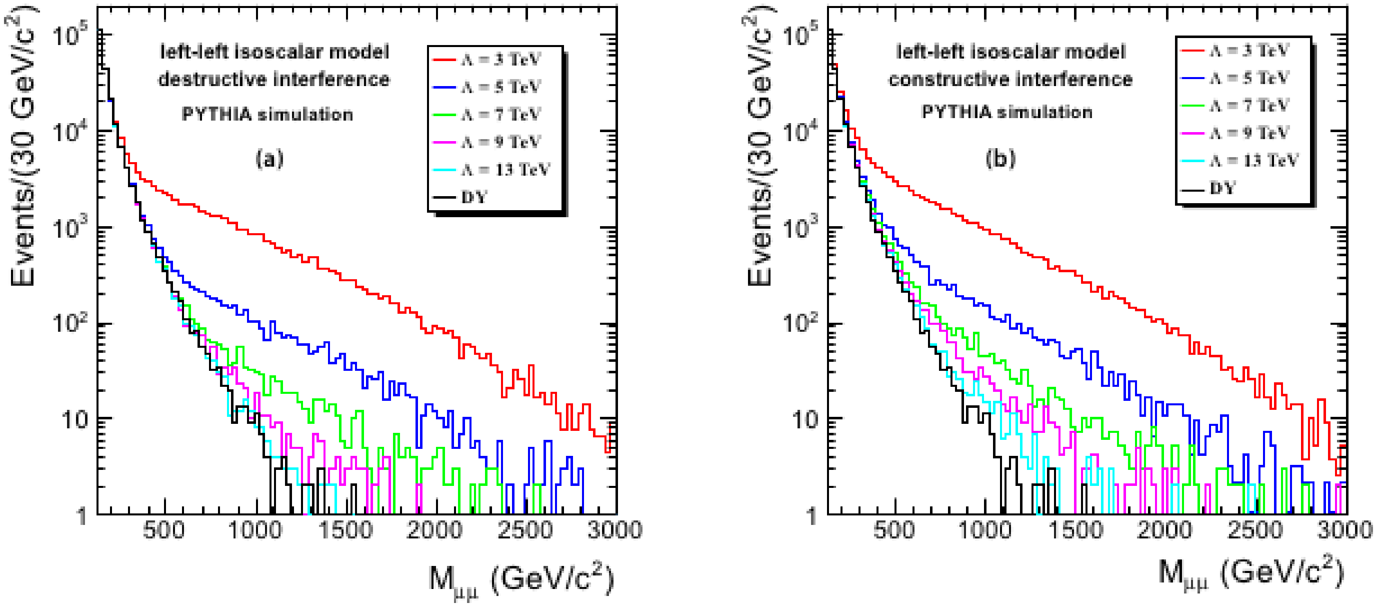
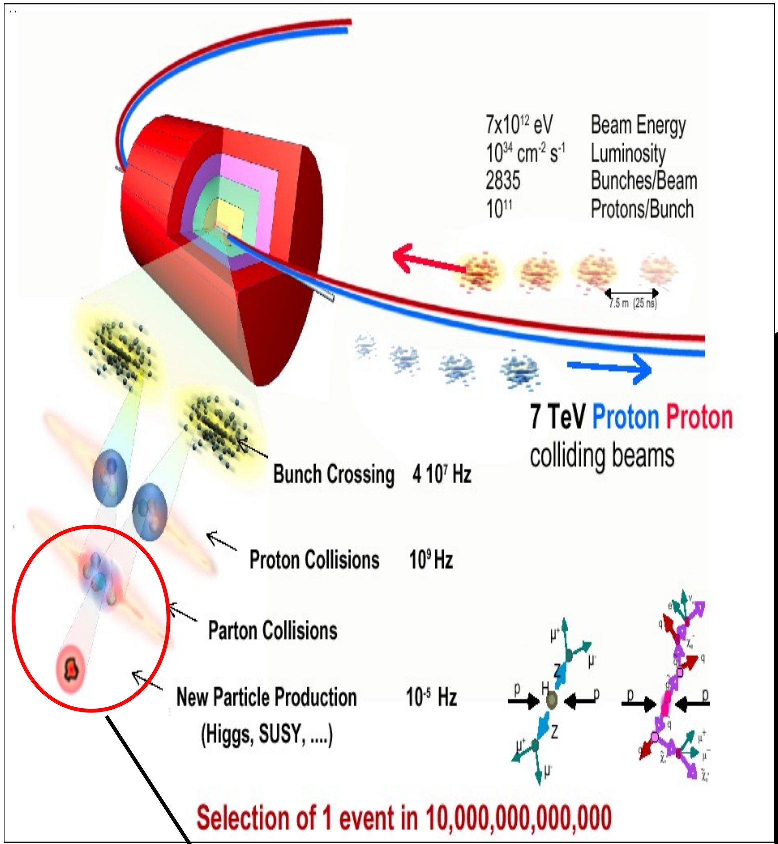
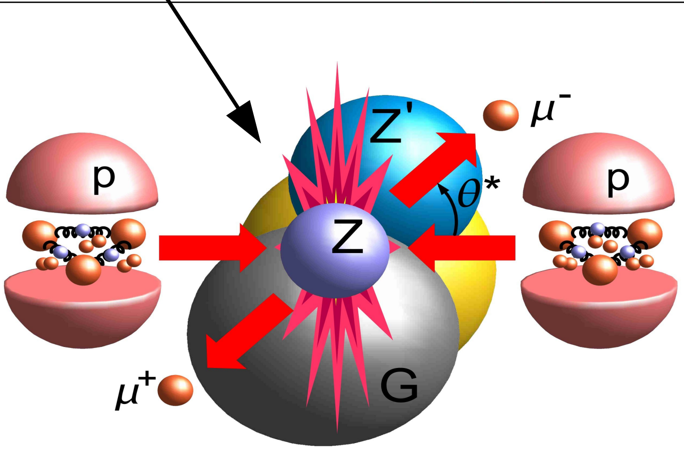


Figure 1: Schematic representation of the addition of DY (left) and CI (right) amplitudes, for common helicity states, contributing to the total cross section for $pp \to X + \mu^+\mu^-$.

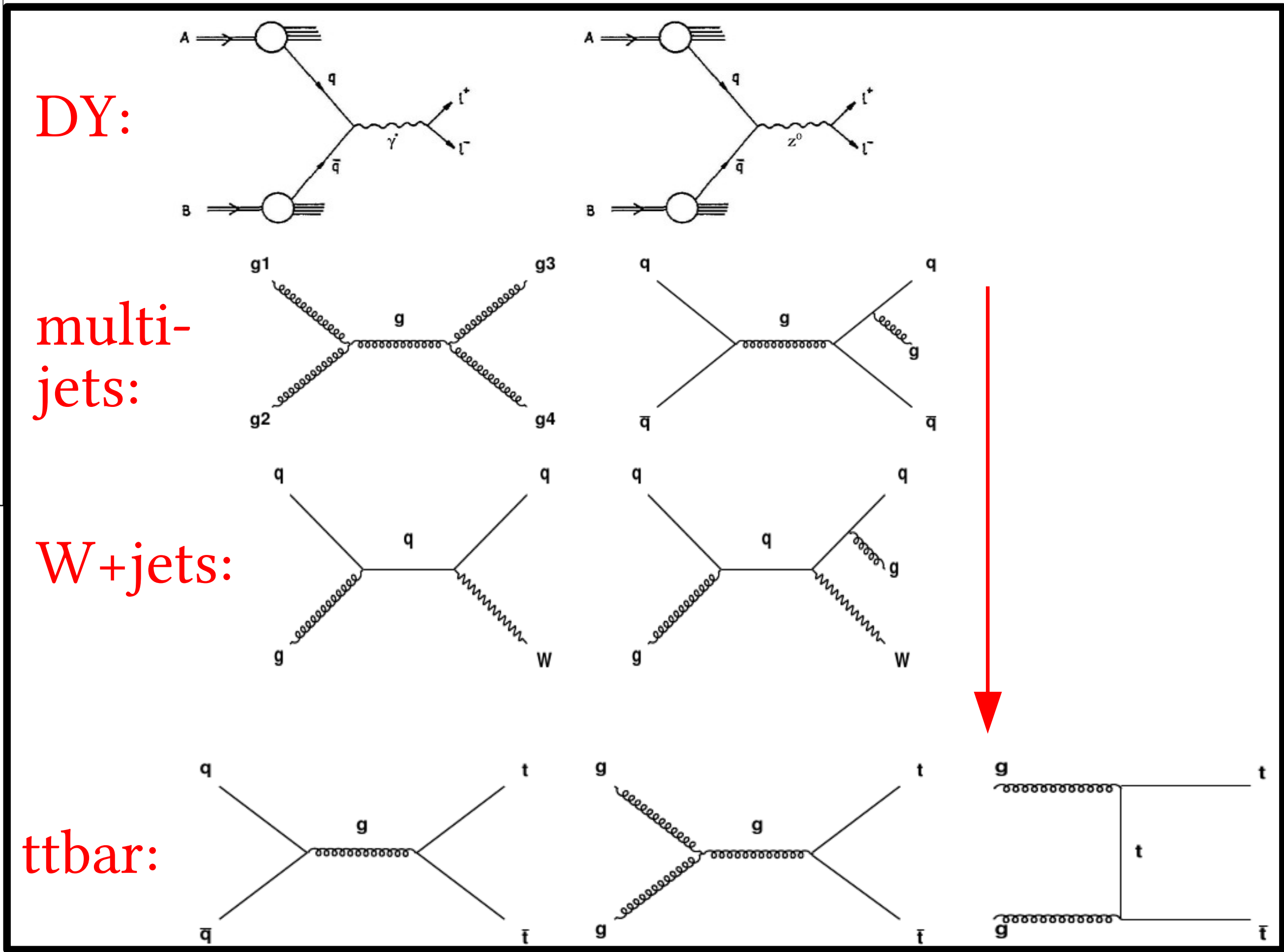


Physics I am interested in !





Backgrounds



Introduction & Out-line of the talk

Why helicity angle distribution is important?

* Distribution of the helicity angles is an important characteristic of the particle interaction

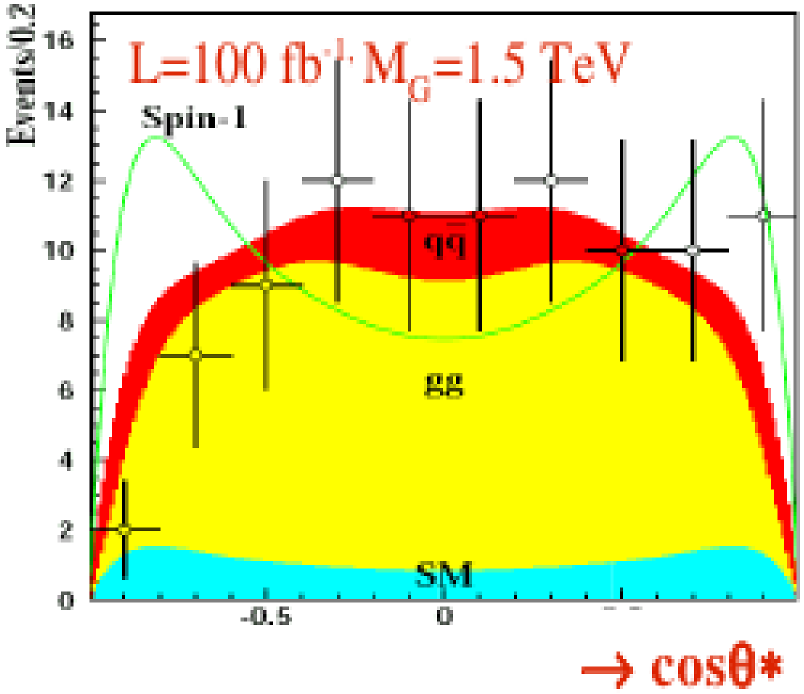
* The proper modeling of the helicity distributions is significant for MC generators

* Helicity angles provide additional information about anomalous couplings and contribute to the sensitivity of searches of new physics.

(1) Bosons (DY, Z'psi and RSG) kinematics
  * $M_{DY} > 120\ GeV/c^2$
  * $M_{DY} > 700\ GeV/c^2$

(2) Collins Soper Frame,
  * results from CMS using HEEP events

(3) Center of Mass Frame,
  * results from CMS using HEEP events



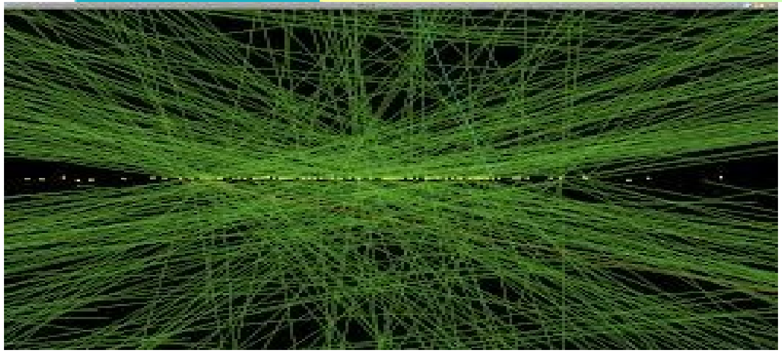
MC & Data sets

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

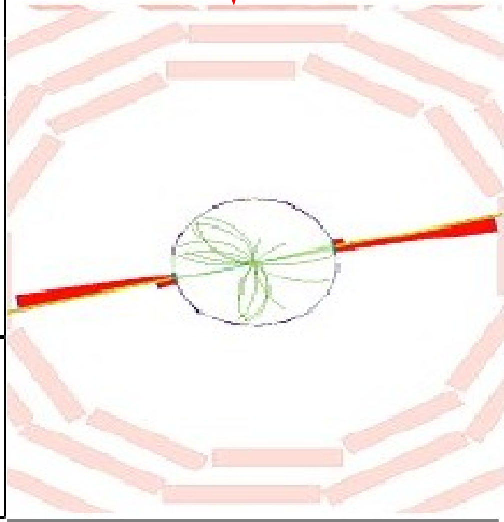
Event Selection (HEEP)



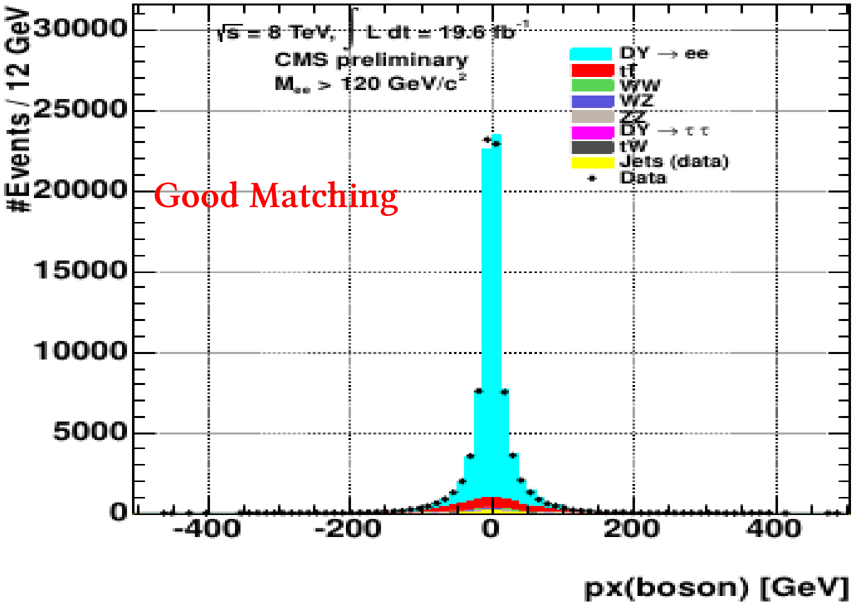
Before selection

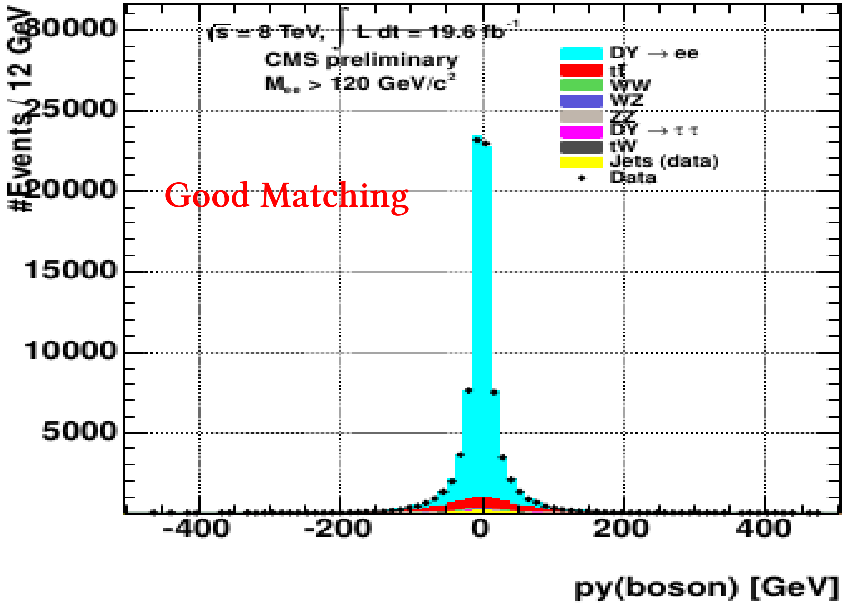
Sh. Elgammal et al., CMS AN – 2012/415

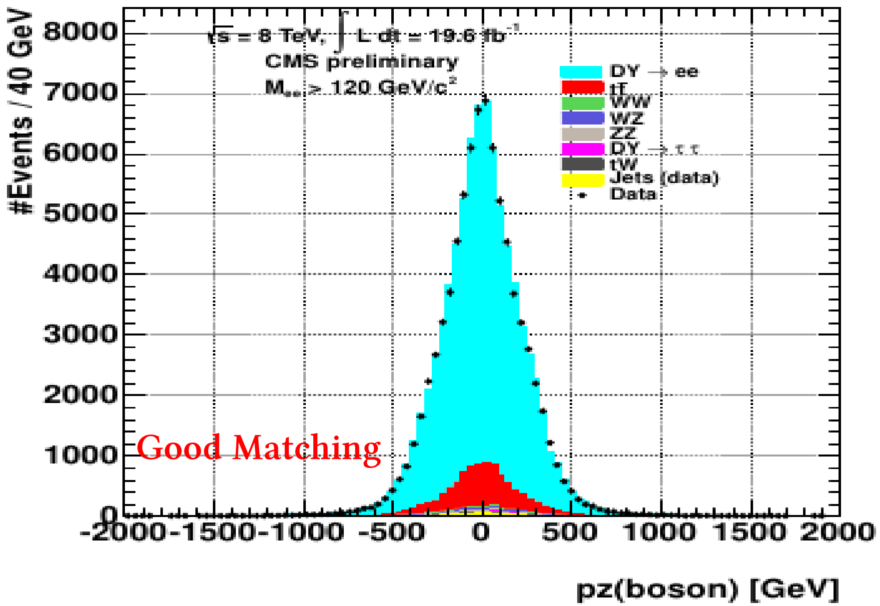
	variable	barrel	endcap
Kinematics cuts	E_T	> 35 GeV	> 35 GeV
	$\|\eta_{SC}\|$	< 1.442	$1.56 < \|\eta\| < 2.5$
	seed	ECAL seeded	ECAL seeded
	missing hits	<=1	<=1
	$\|d_{xy}\|$	<0.02	<0.05
	$\Delta\eta_{in}$	< 0.005	< 0.007
	$\Delta\phi_{in}$	< 0.06	<0.06
Shower shape cuts	H/E	< 0.05	< 0.05
	E^{2x5}/E^{5x5}	> 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

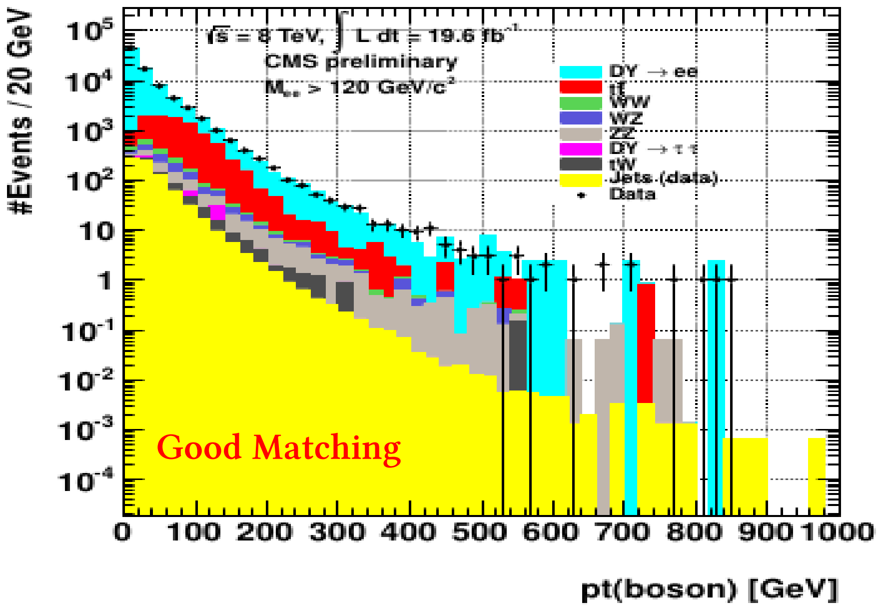


Boson kinematics in lab Frame
(M_{DY} > 120 GeV/c^2)

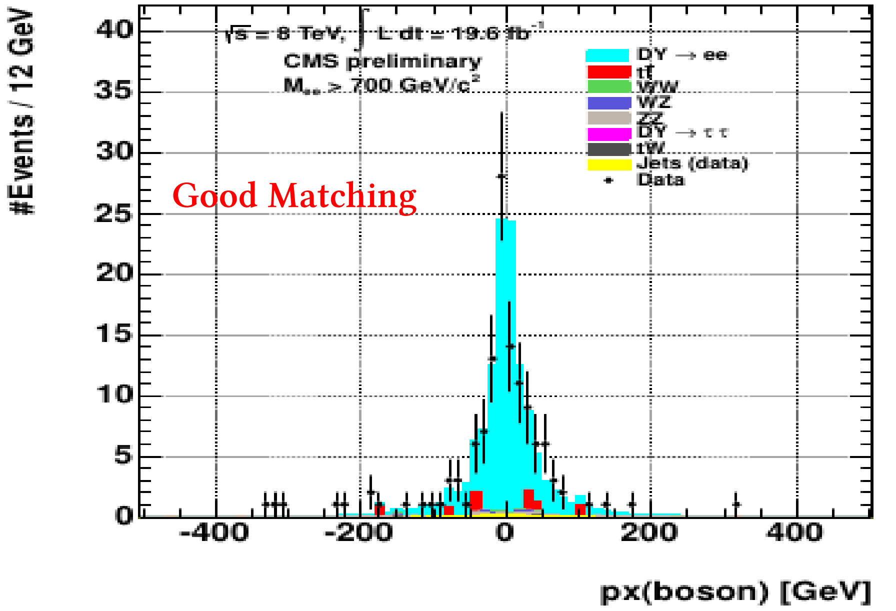


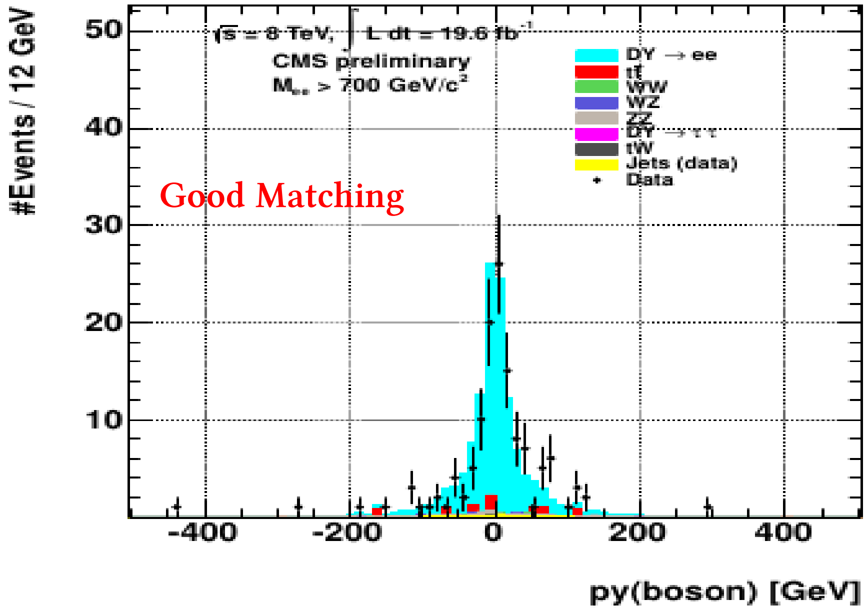


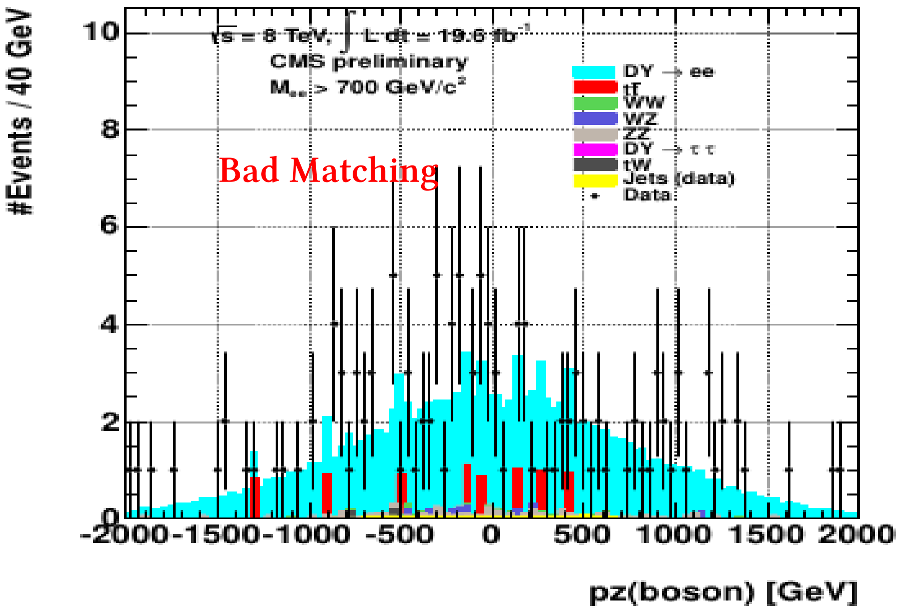


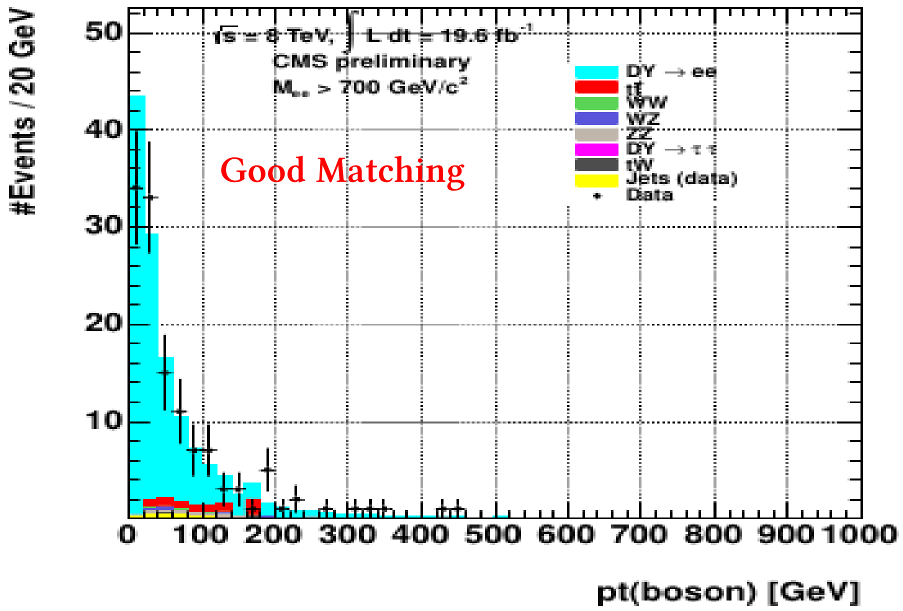


Boson kinematics in lab Frame (M_{DY} > 700 GeV/c^2)

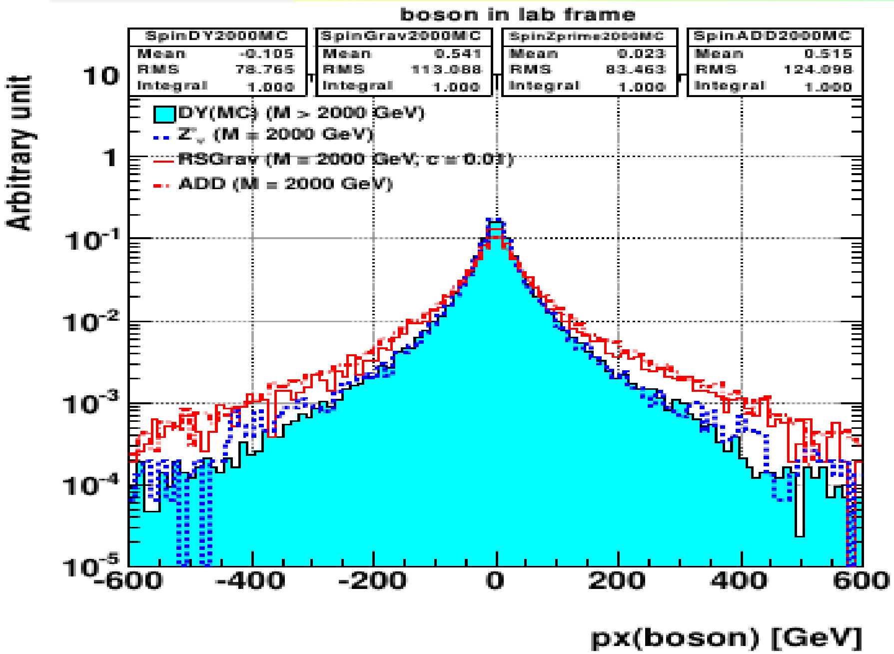


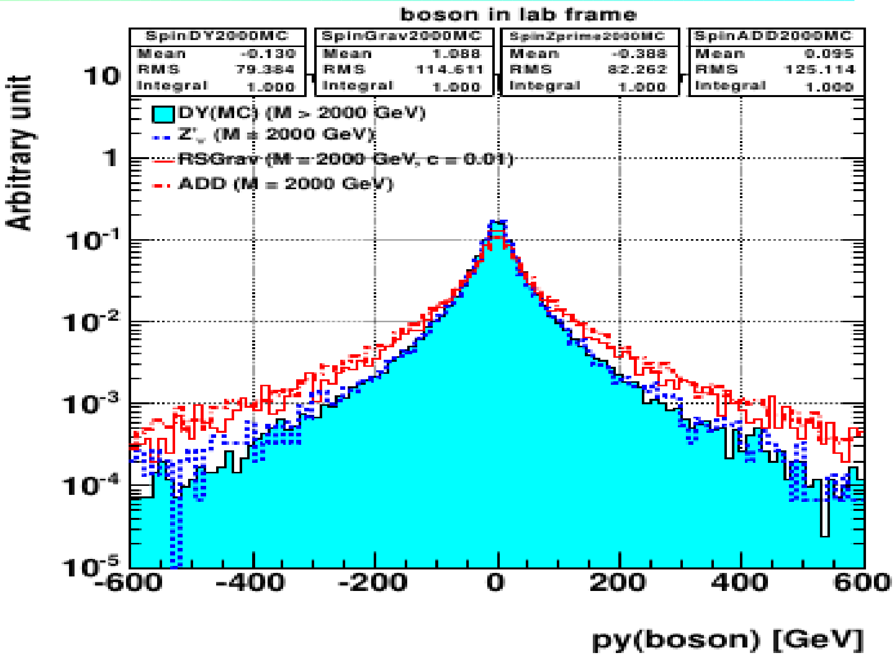


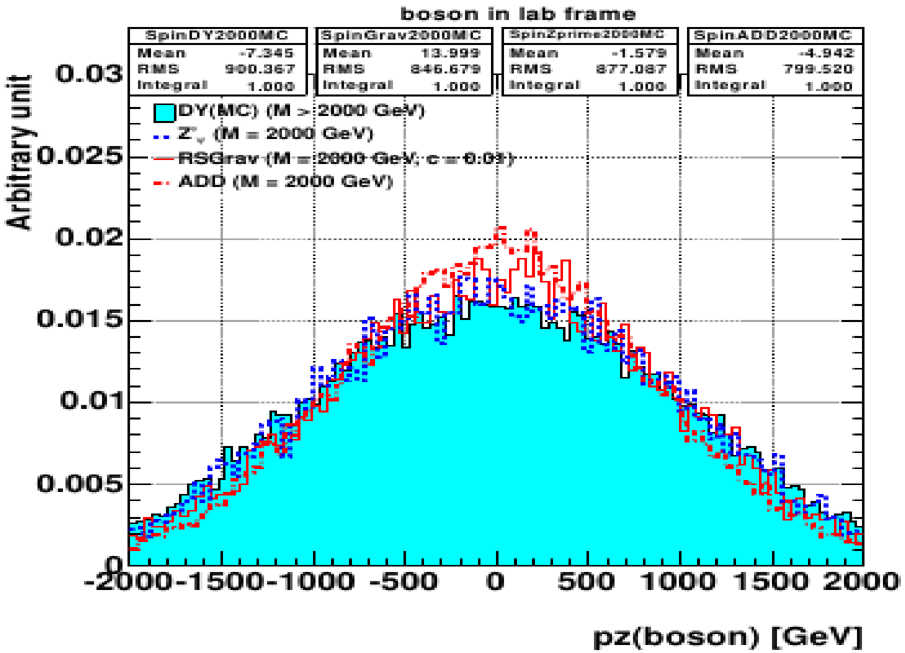


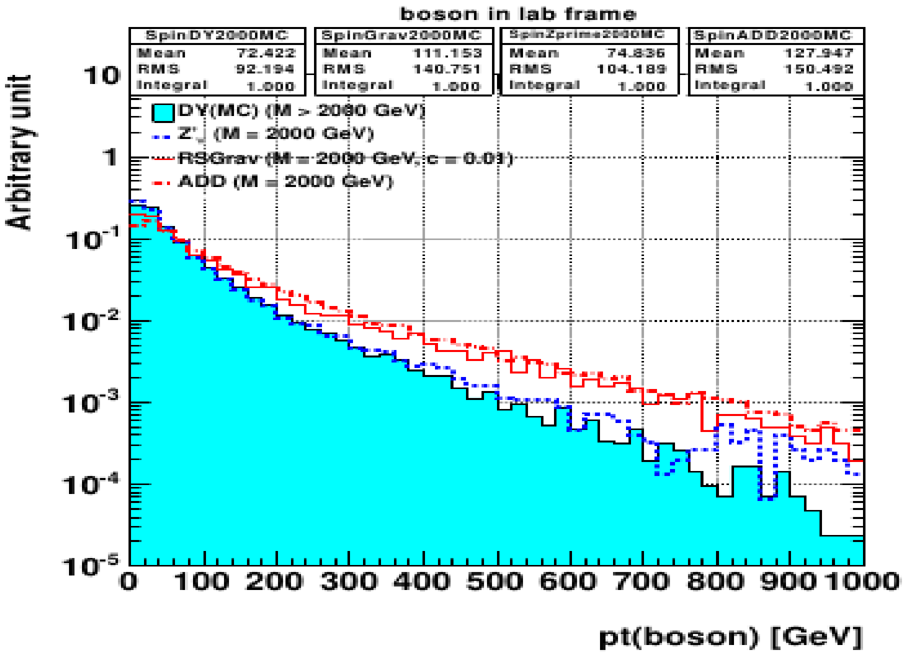


Boson kinematics in lab Frame (for DY & signals)

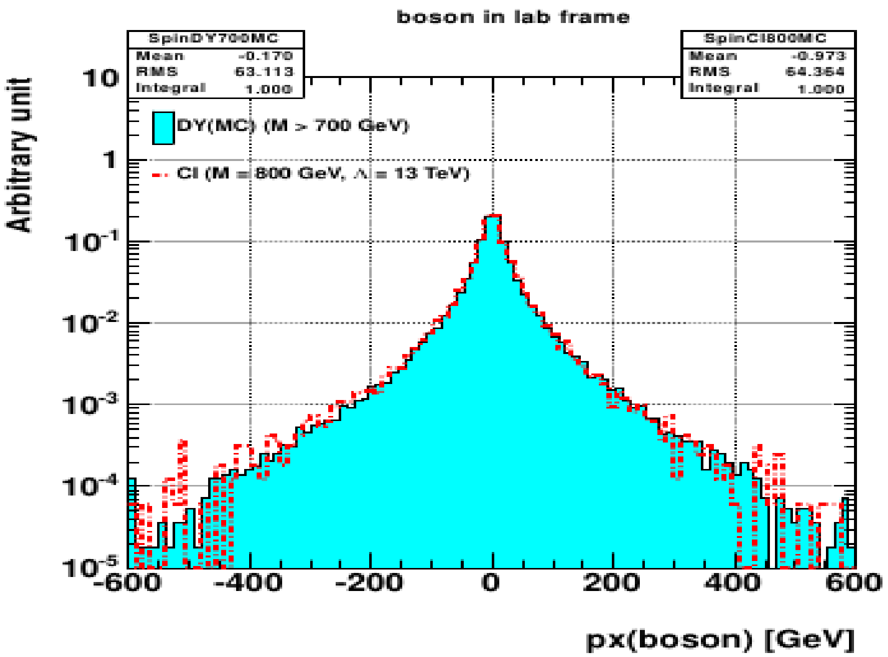


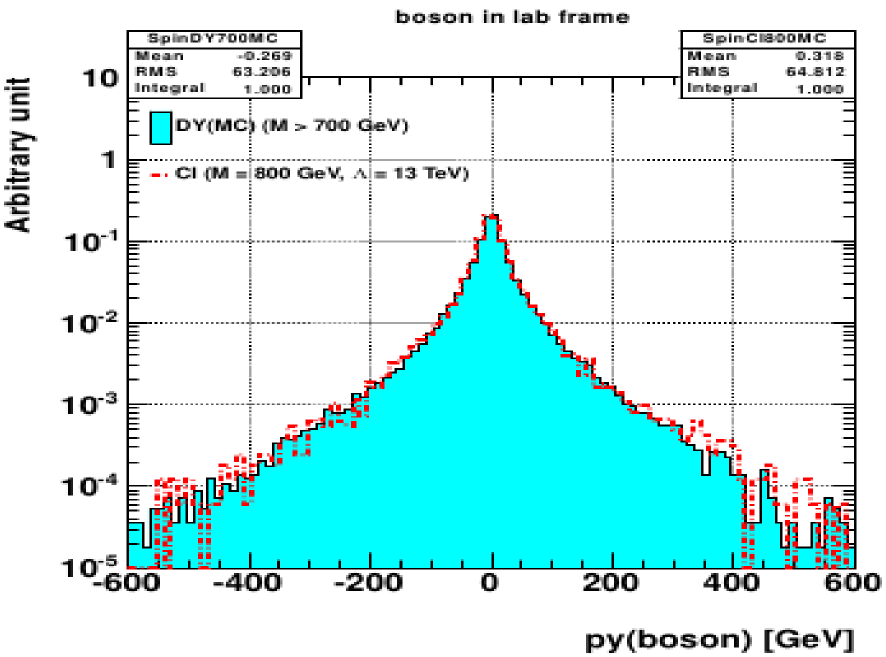


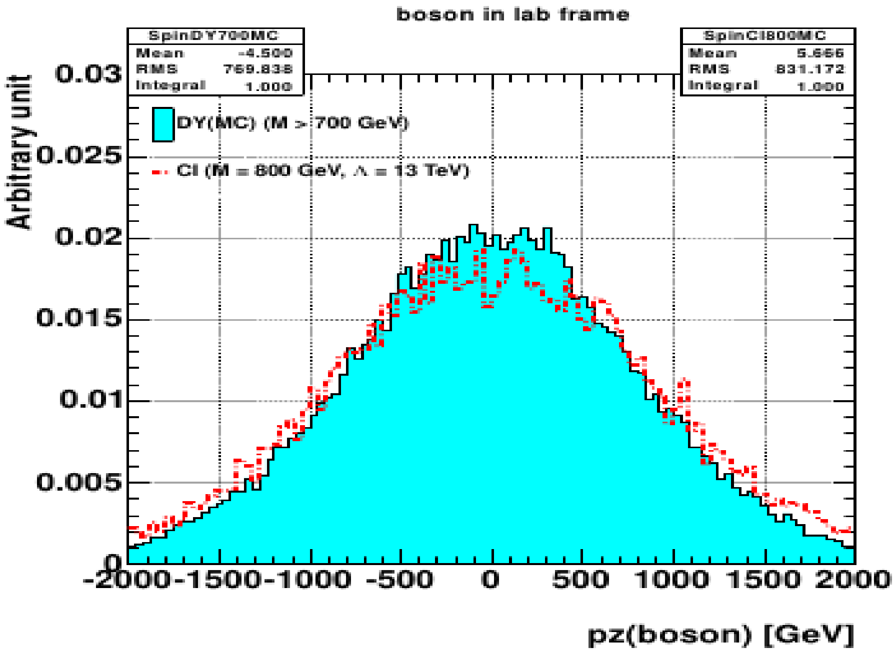


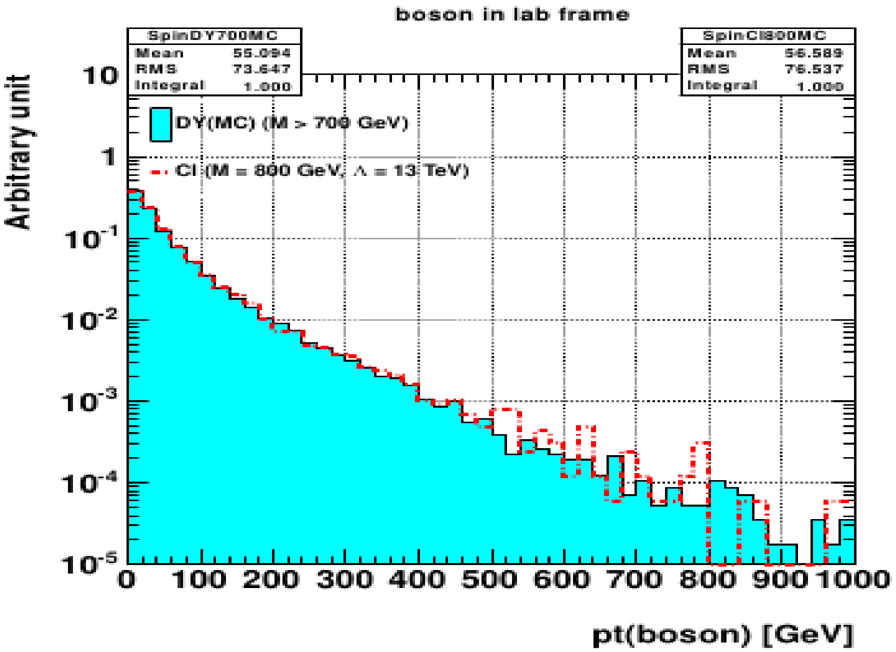


Boson kinematics in lab Frame (for DY & CI model)

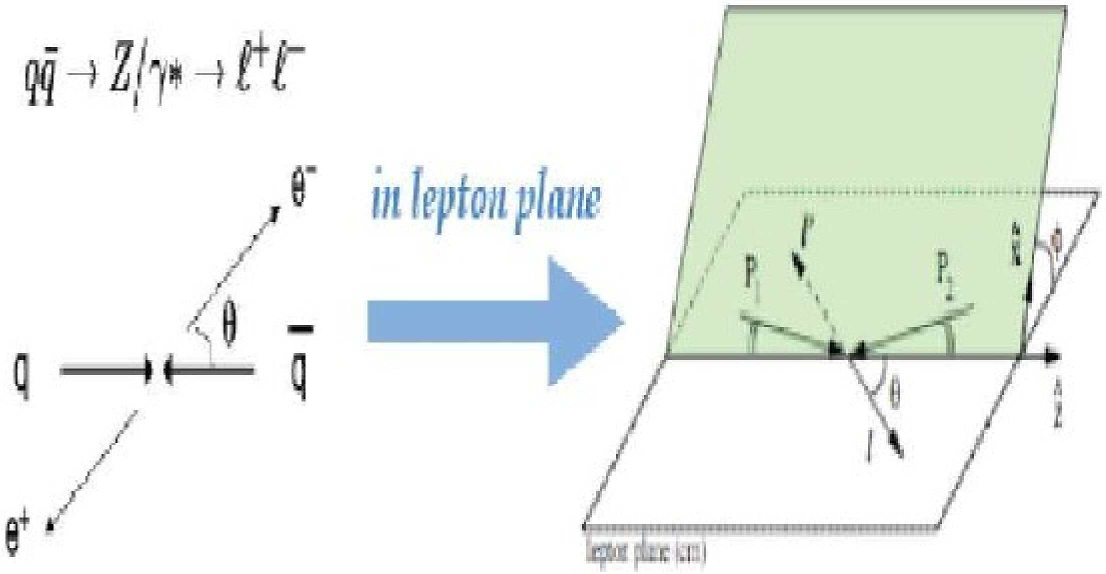






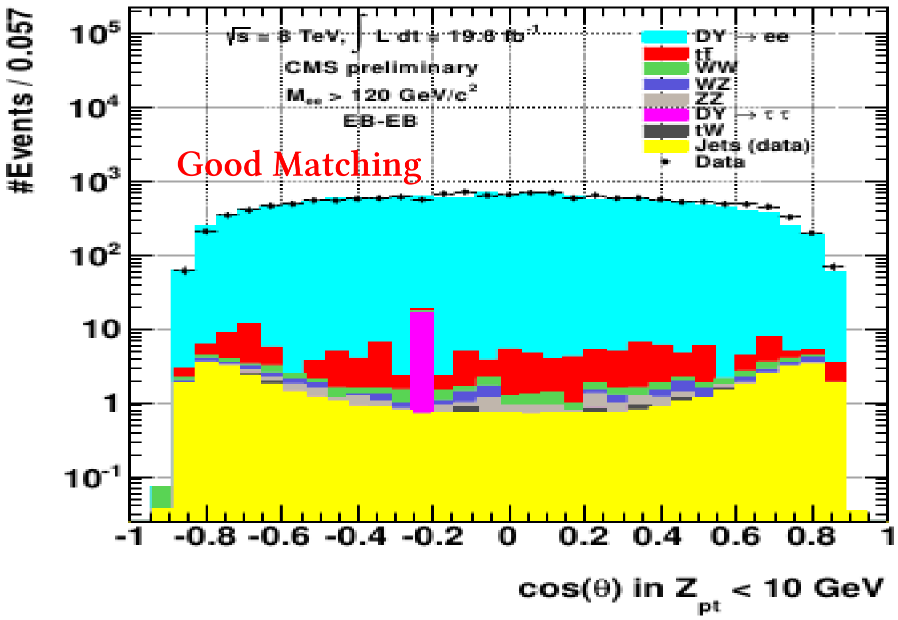


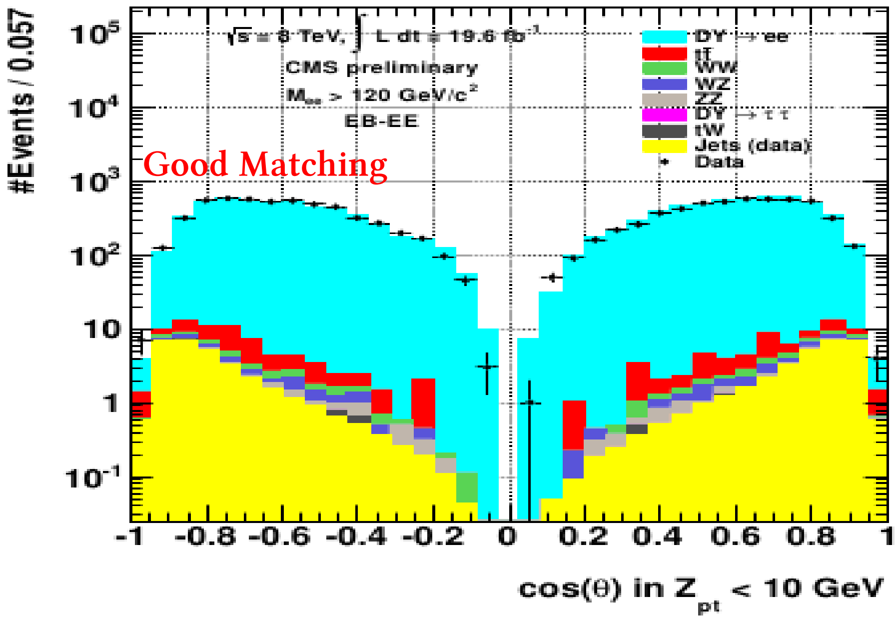
Collins Soper Frame

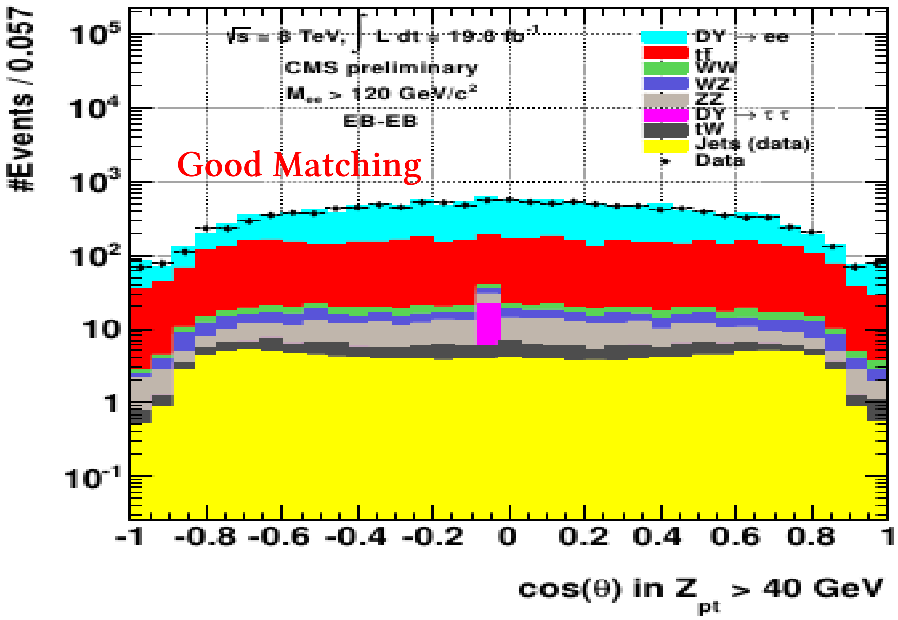


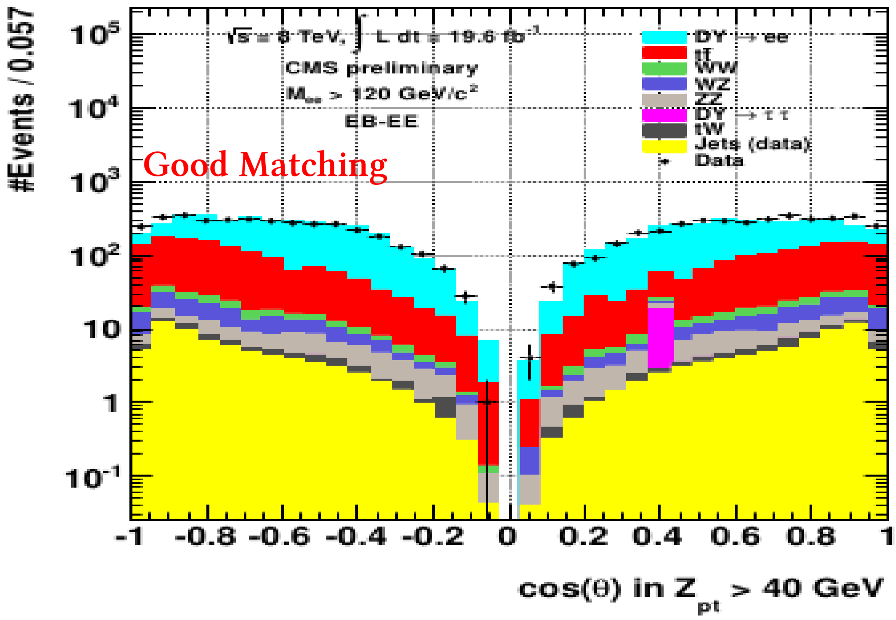
Collins Soper frame is characterized by 2 properties; the y axis is perpendicular to the plane spanned by the two hadron momenta P_1 and P_2, the z-axis bisects the proton and minus the other proton directions in the boson rest frame.

Collins Soper Frame (cos[theta])

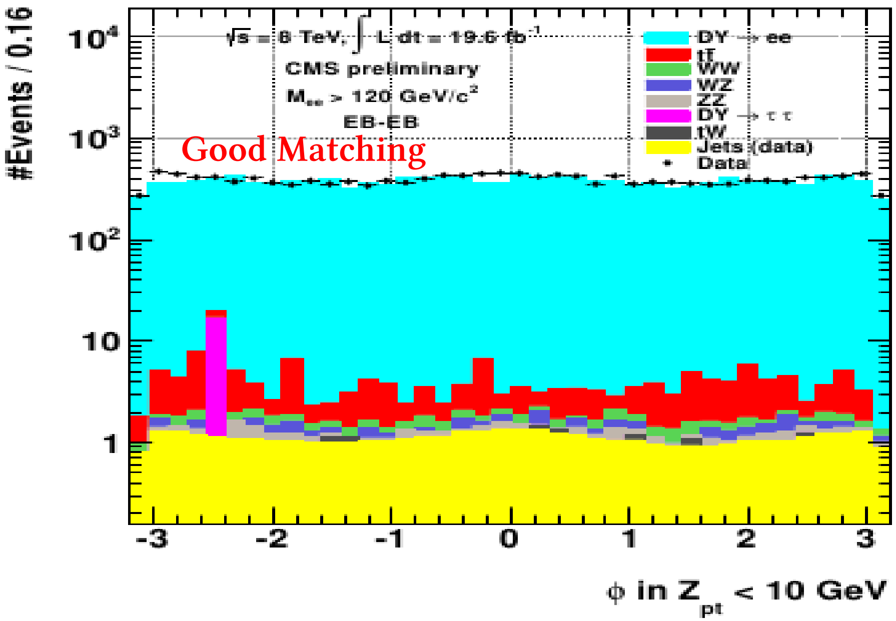


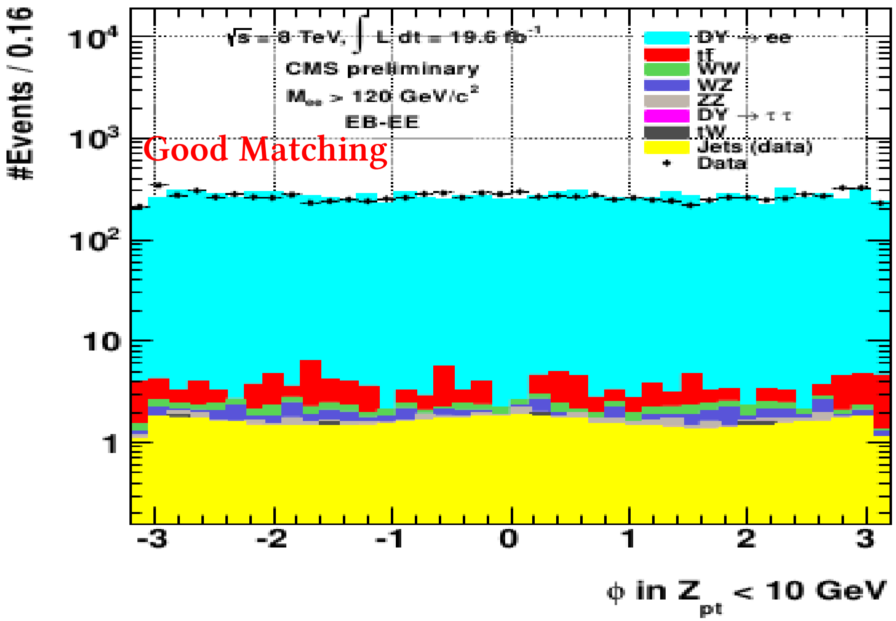


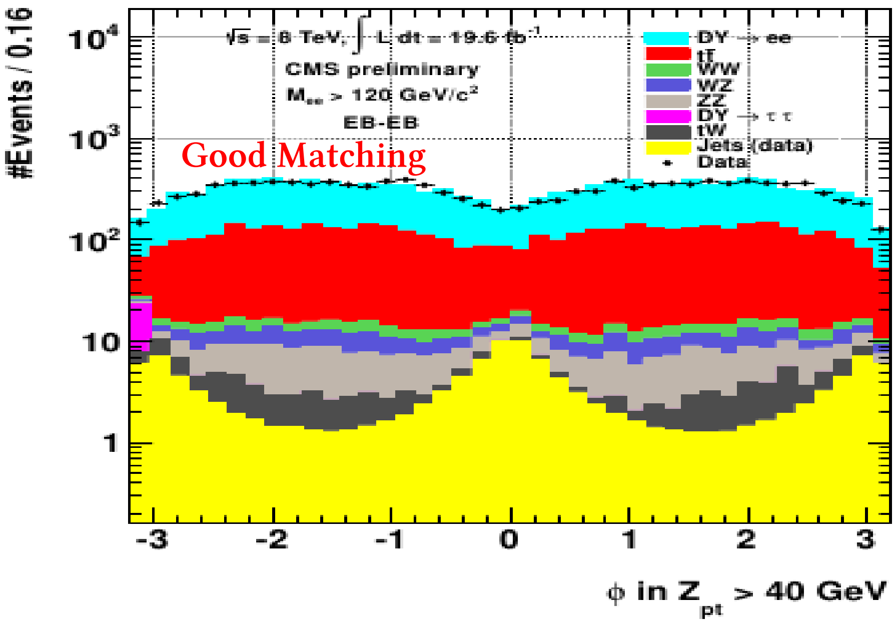


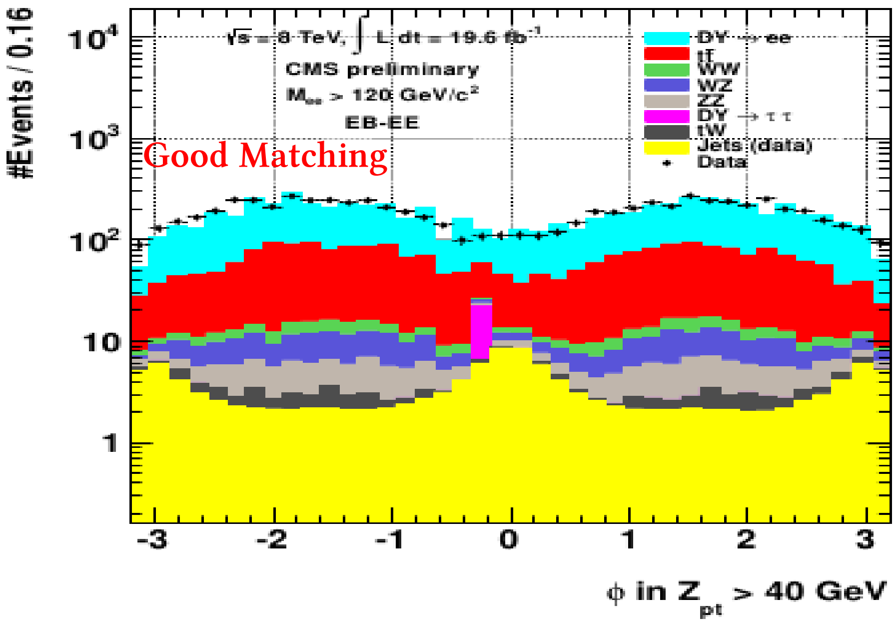


Collins Soper Frame (Phi)

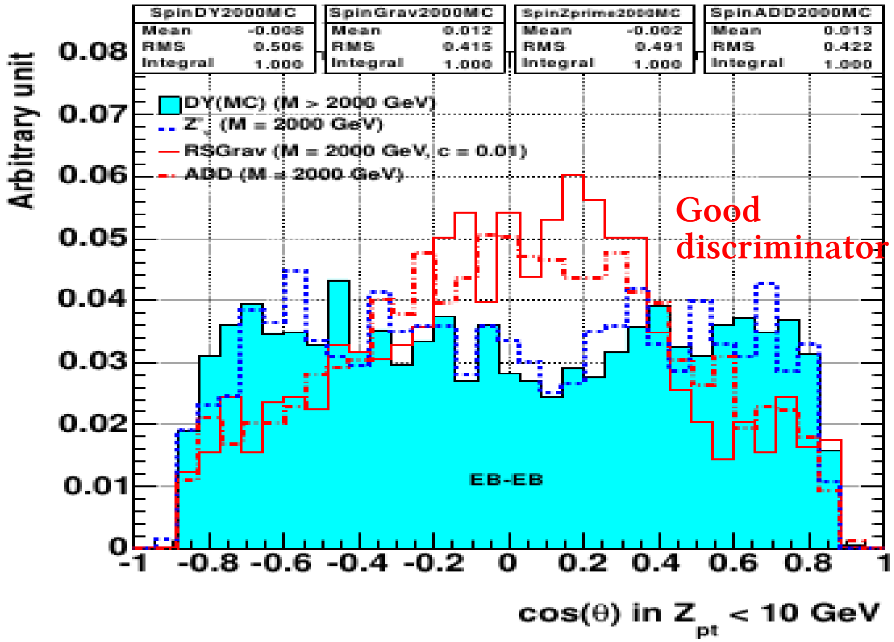


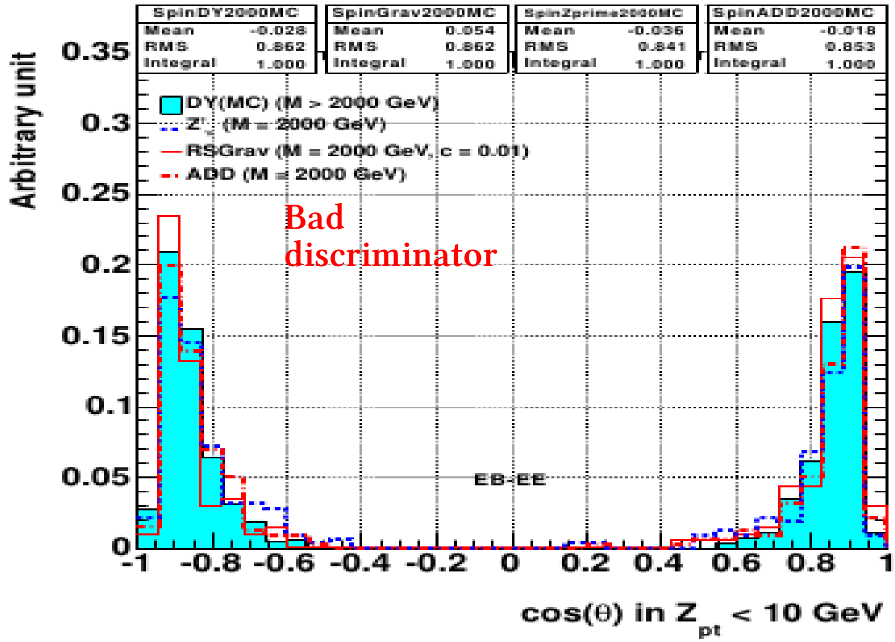


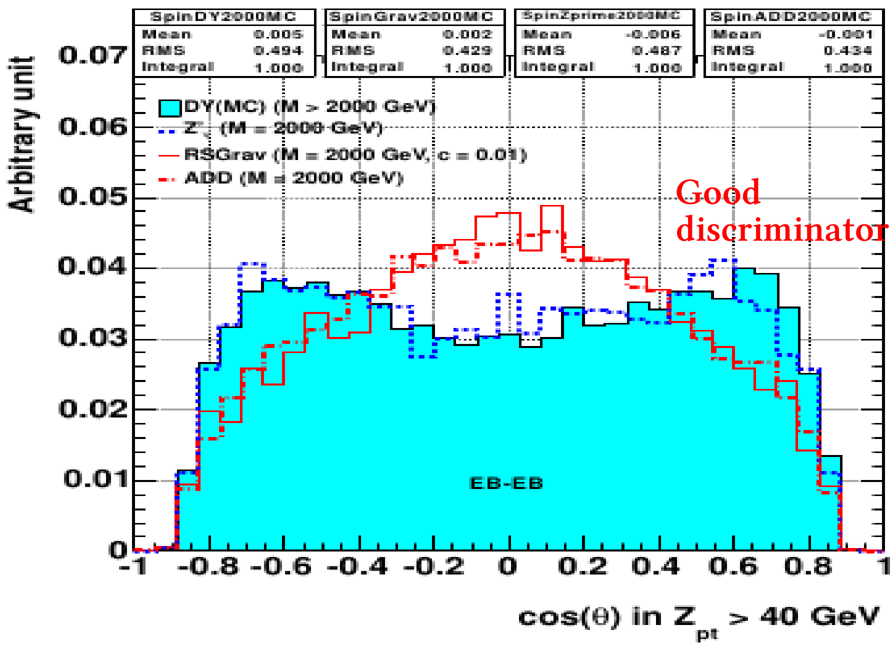


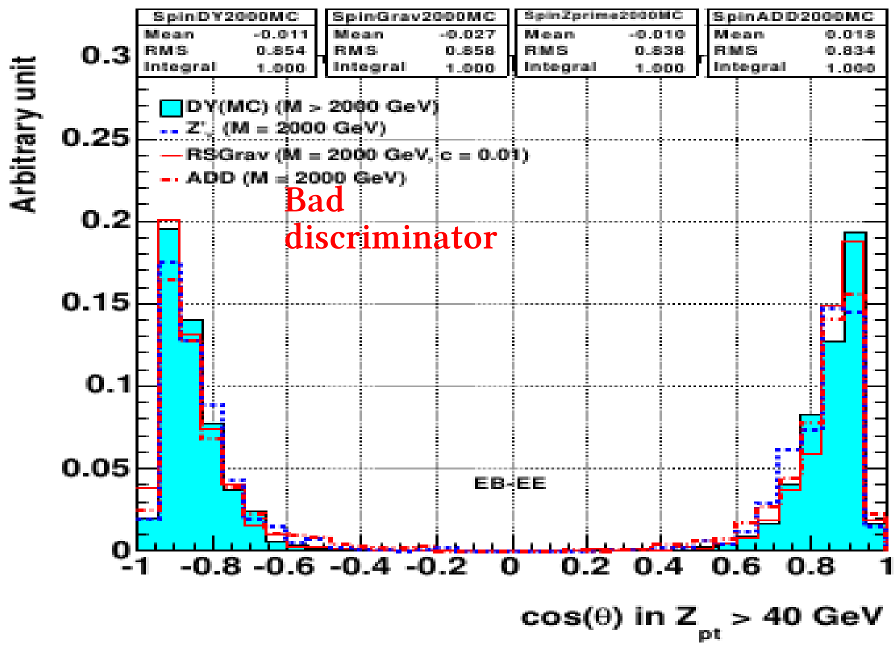


Collins Soper Frame
(DY > 2000 GeV & Signals)

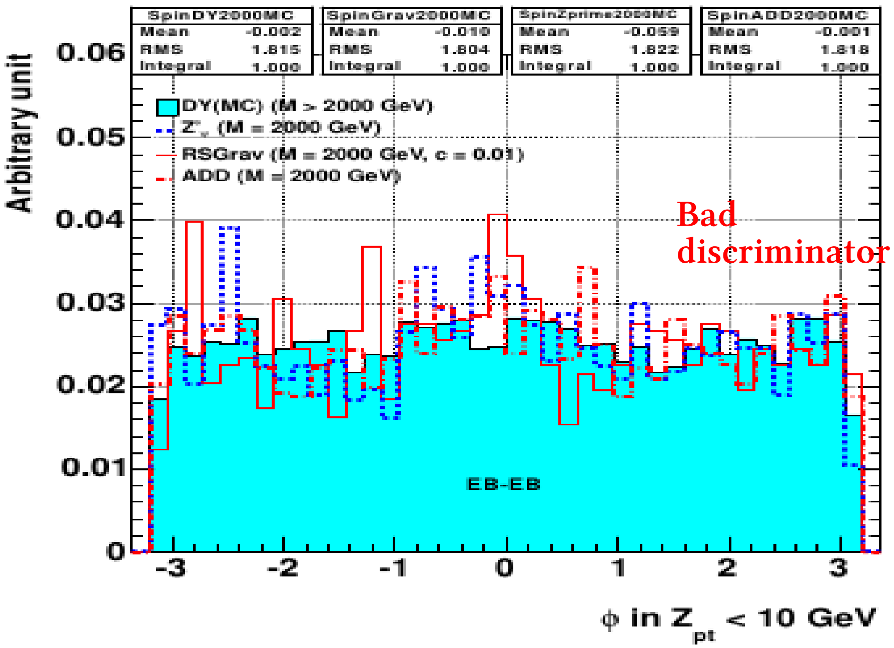


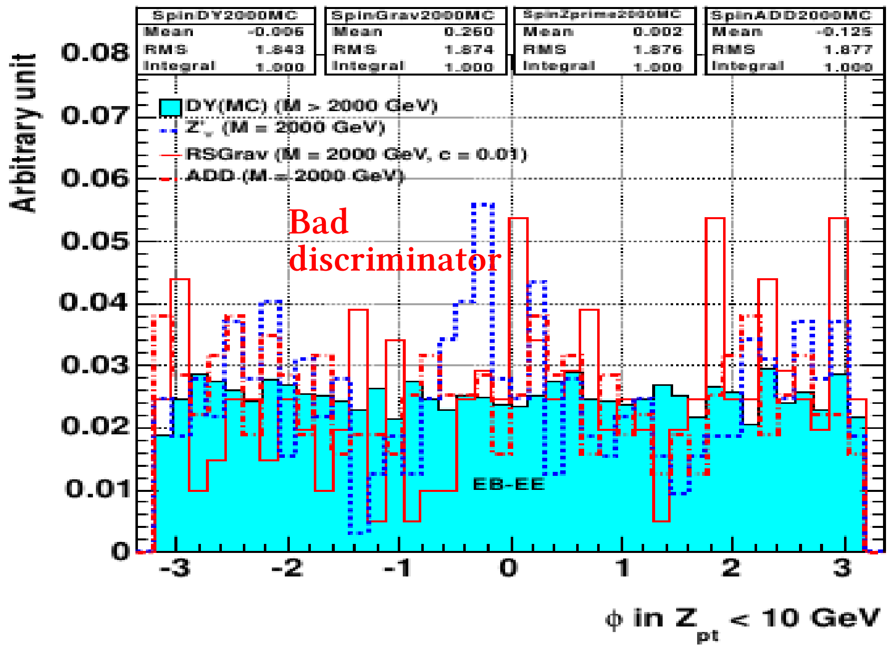


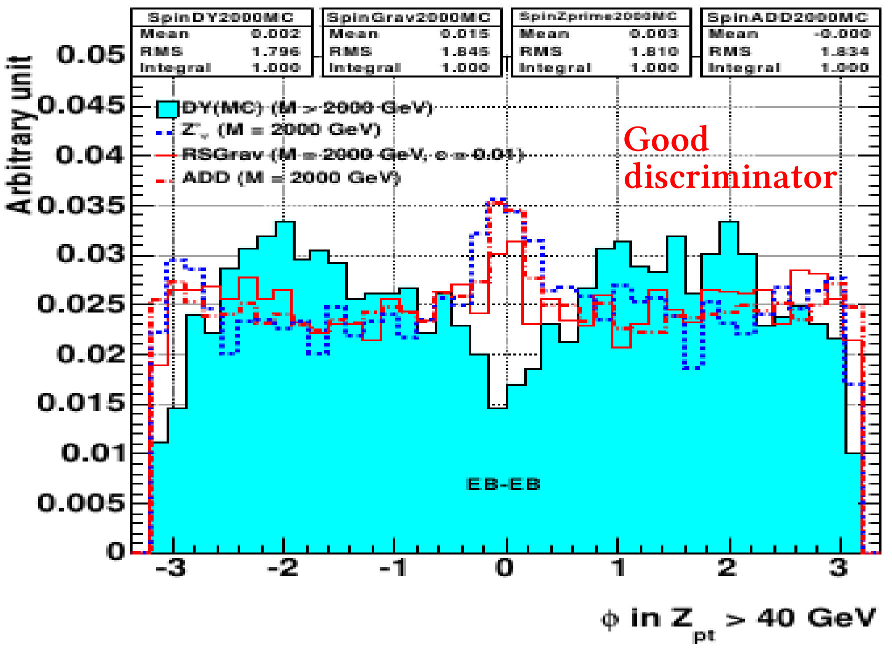


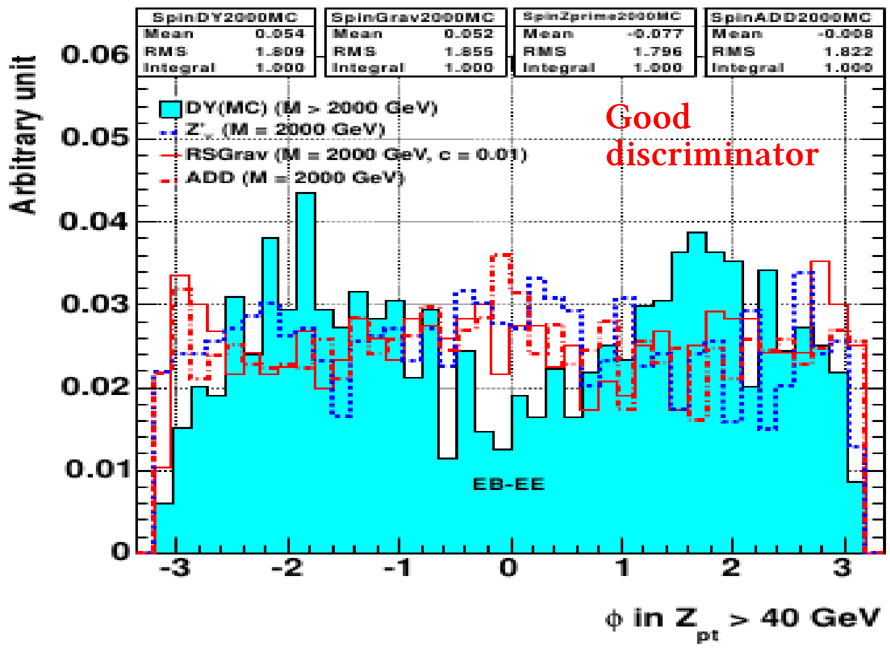


Collins Soper Frame
(DY > 2000 GeV & Signals)

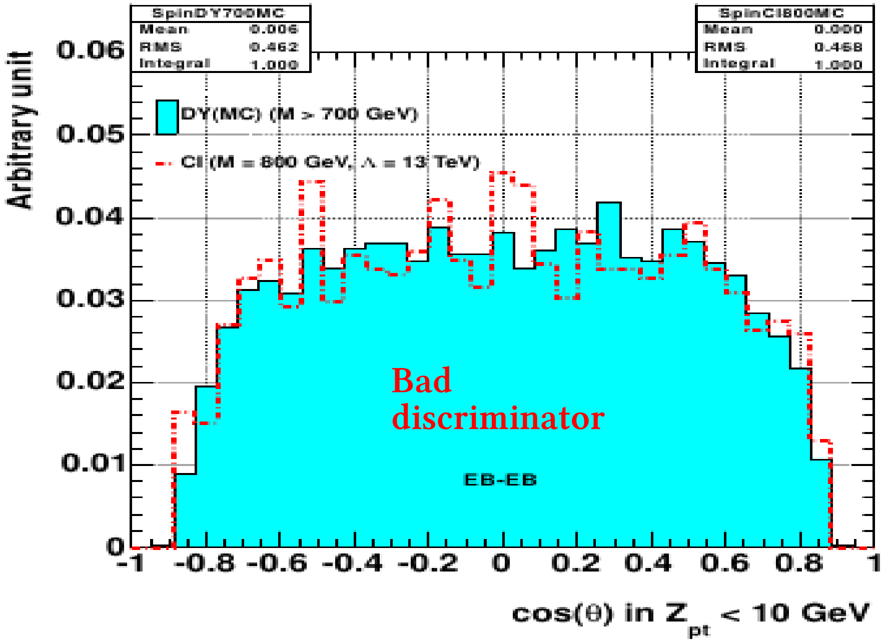


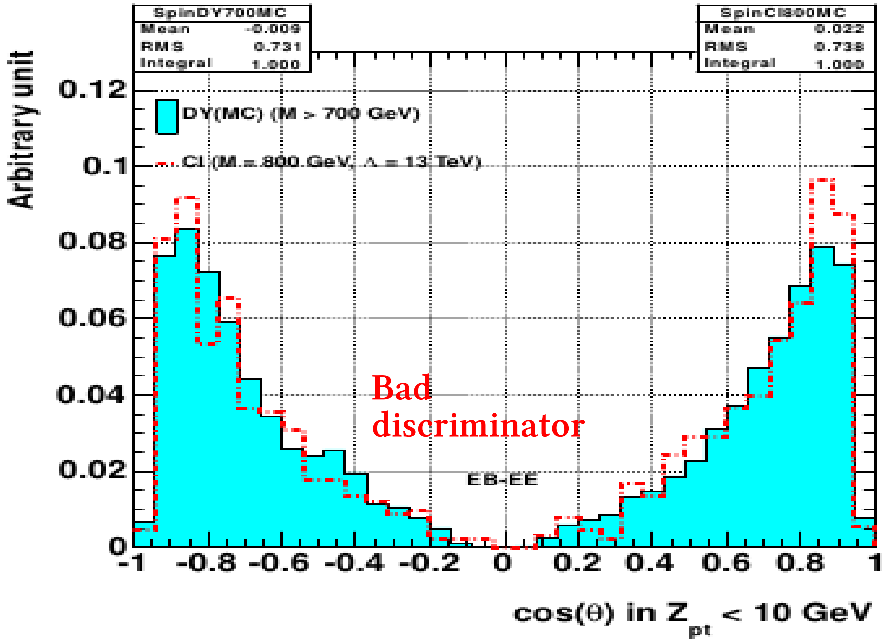


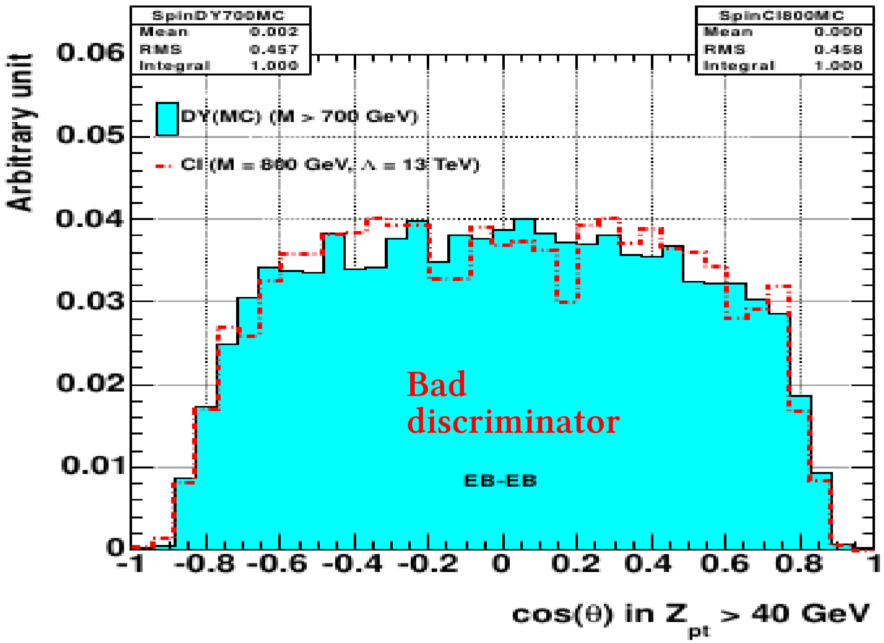


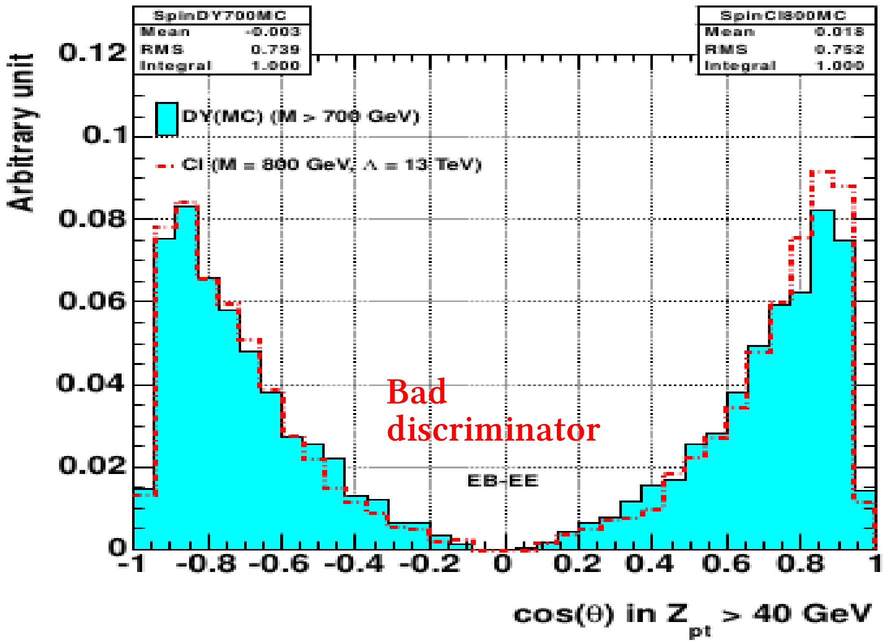


Collins Soper Frame
(DY > 2000 GeV & CI model)

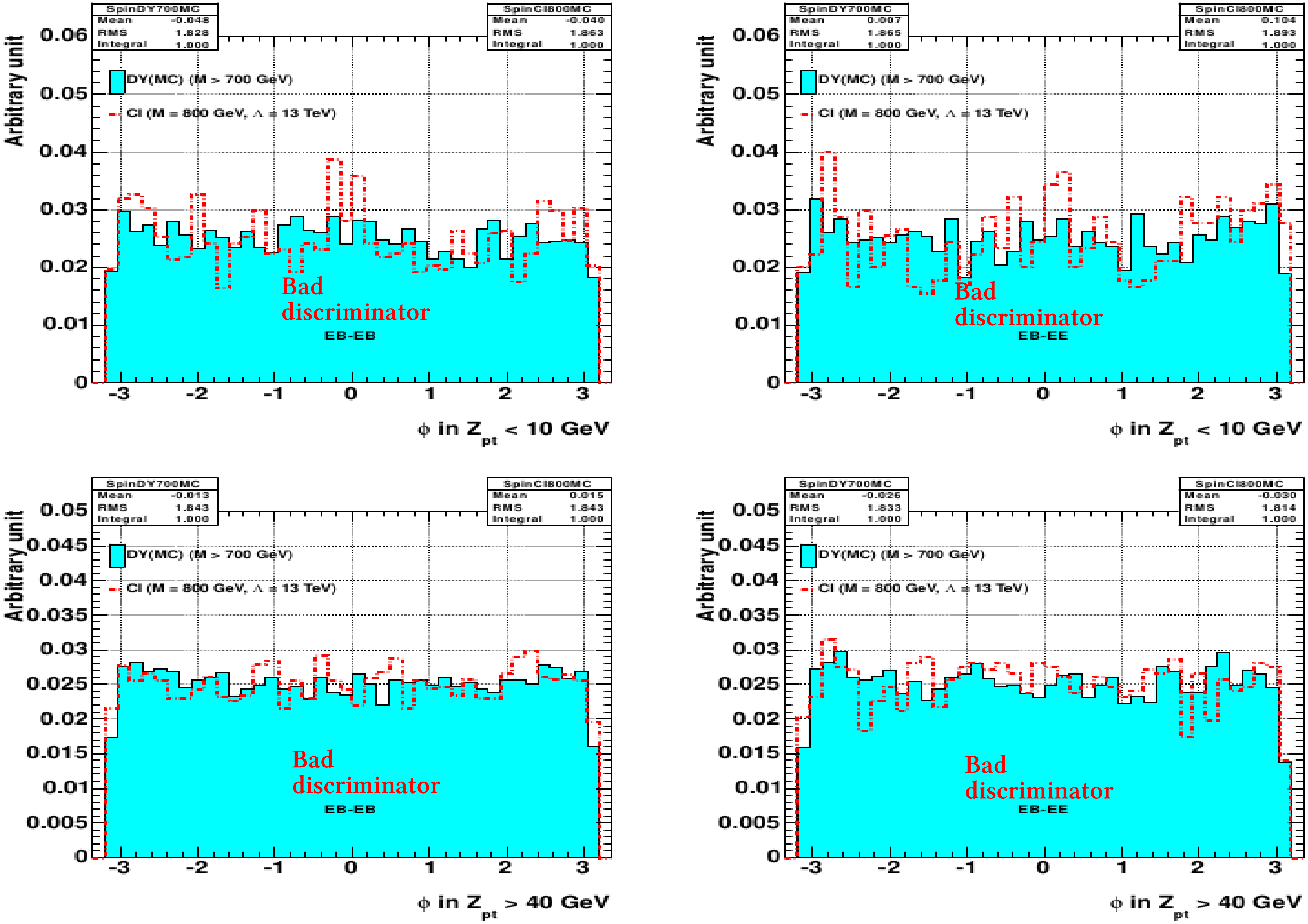


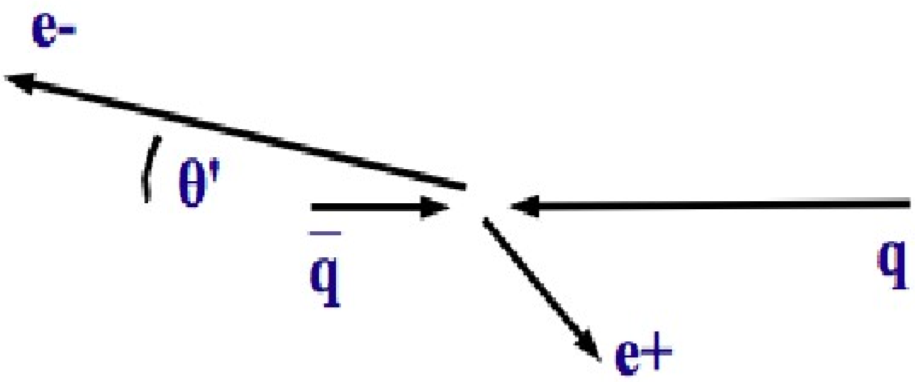




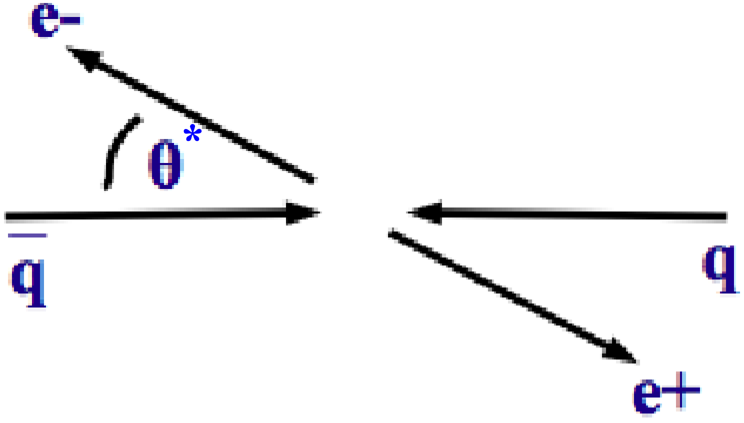


Collins Soper Frame
(DY > 2000 GeV & CI model)





Lab Frame

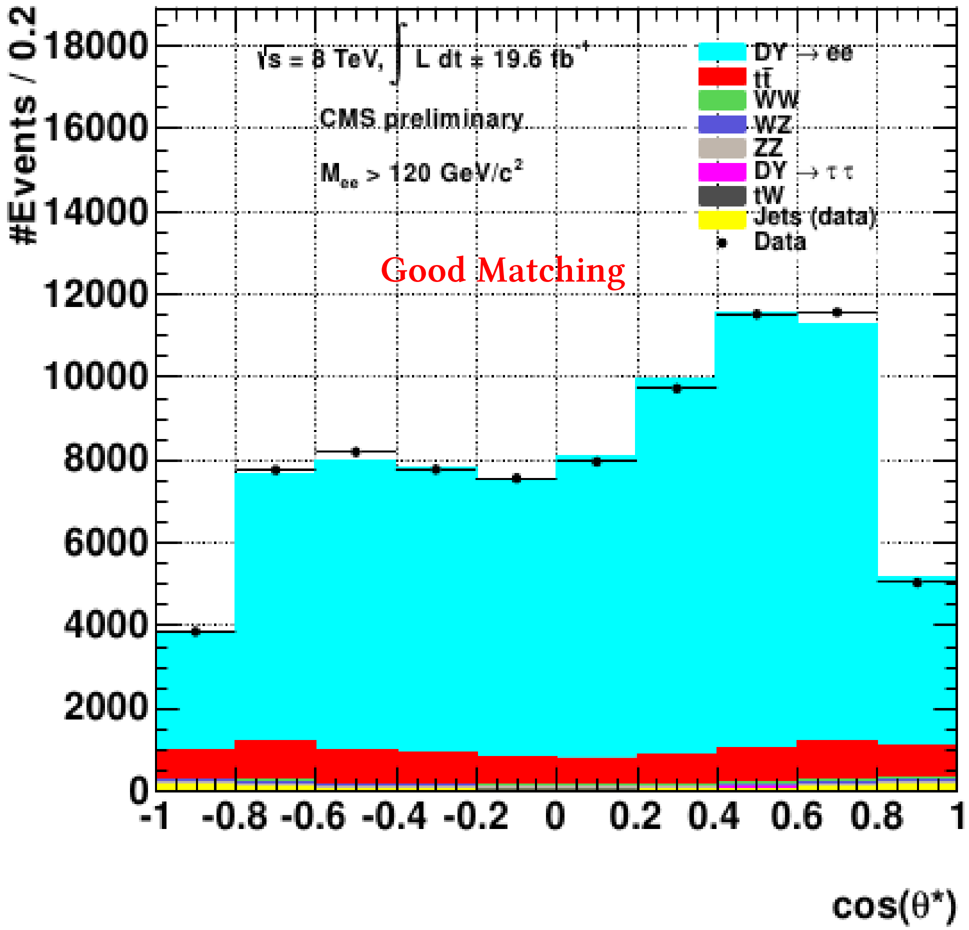


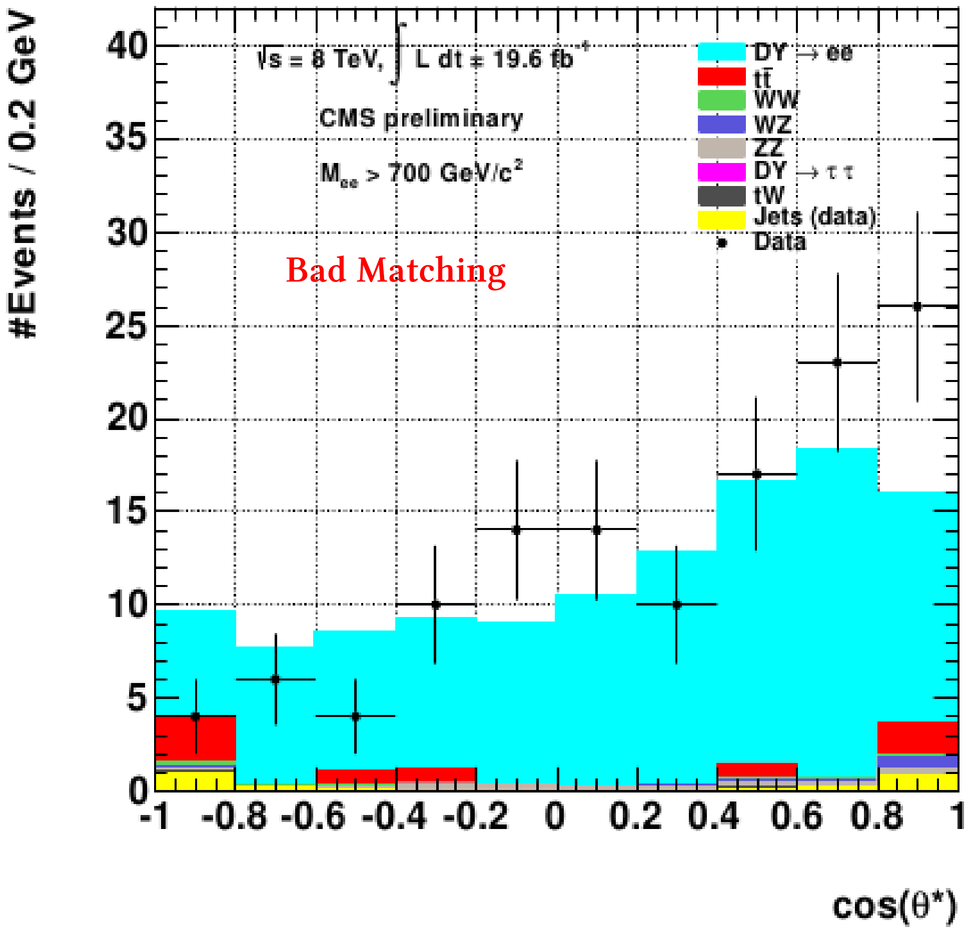
Centre of Mass Frame

- Then θ^* is computed as the polar angle between the electron and the boosted direction of the heavy boson in the boson rest frame. In addition the electron and positron candidates are requested to have opposite charges, in order to identify the electron from which $\cos(\theta^*)$ is computed

- RS graviton with spin 2 can be distinguished from the SM background and Z' bosons with spin 1 using the $\cos(\theta^*)$

Helicity Dist. for Boson at Rest Frame (DY > 120 GeV & Data)

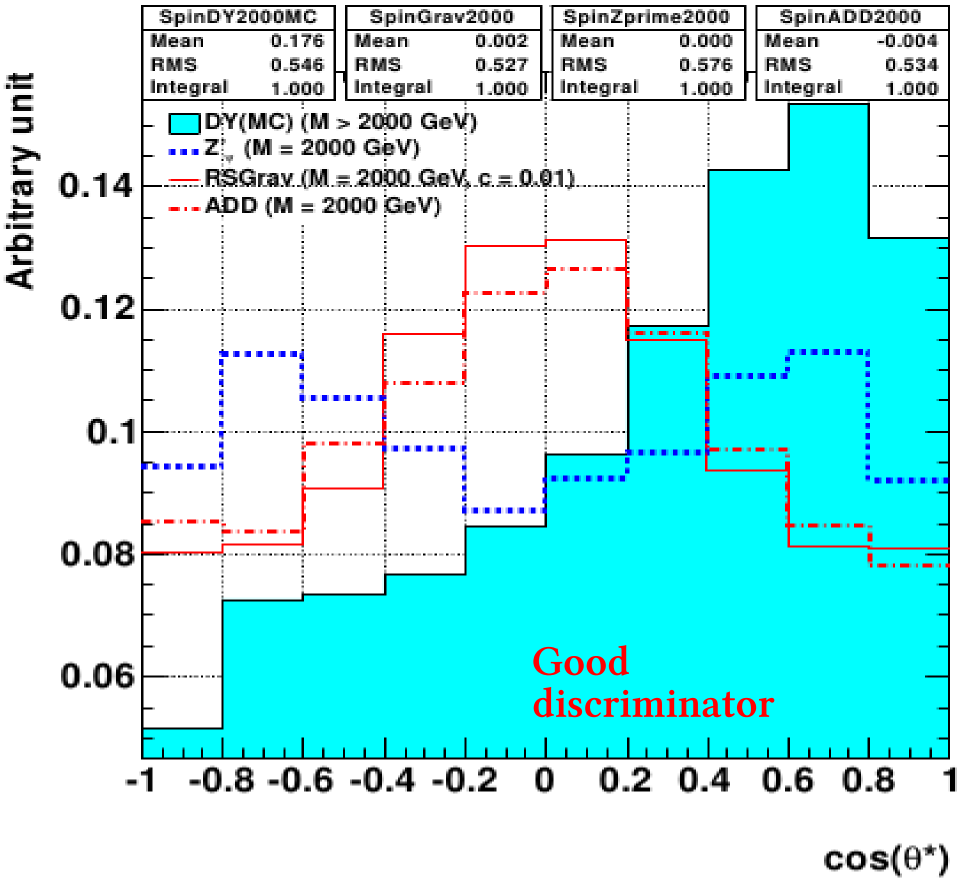


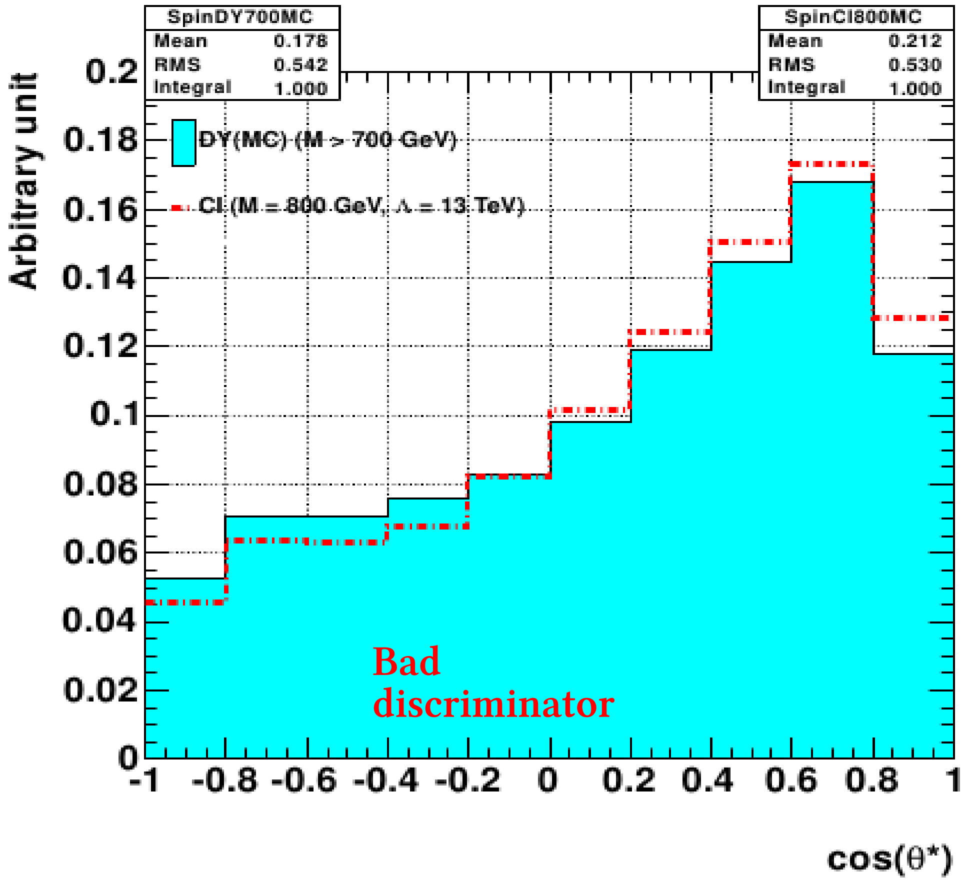


Data is compatible with the MC at high mass (M>120 GeV/c^2)

Some how data is compatible with the DY MC at high mass (M>700 GeV/c^2), however more data are needed to fully understand these plots

Helicity Dist. for Boson at Rest Frame (DY > 2000 GeV & Signals)





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 polar angles of the final state electrons (θ^*) at boson rest frame are good variables to distinguish between the parent bosons [G (ADD or RS) and Z'] and the DY b.g. Process.

(3) Angular distribution is not good variable to distinguish between CI model from DY bg.

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

Future Work

(1) Adding a section related to Forward Backward asymmetry

(2) Confirming gluon spin 1 results using CMS data (in CS frame)

(3) Writing AN when the study is finished and mature

Backup

Summary of Collins Soper Frame

(1) Collins Soper Frame (at DY tail (M > 120 GeV/c^2), Boson pt < 10 GeV/c)

(a) Cosθ dist

* EB-EB Good matching data & DY(MC), Good discriminator
* EB-EE Good matching data & DY(MC), Good discriminator

(b) ϕ dist

* EB-EB Good matching data & DY(MC), bad discriminator
* EB-EE Good matching data & DY(MC), bad discriminator

(2) Collins Soper Frame (at DY tail (M > 120 GeV/c^2), Boson pt > 40 GeV/c)

(a) Cosθ dist

* EB-EB bad matching data & DY(MC), bad discriminator
* EB-EE bad matching data & DY(MC), bad discriminator

(b) ϕ dist

* EB-EB Good matching data & DY(MC), Good discriminator
* EB-EE Good matching data & DY(MC), Good discriminator