Angular Correlations: An Effective Strategy to distinguish BSM Physics in Present & Future Colliders

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Anomalies 2020

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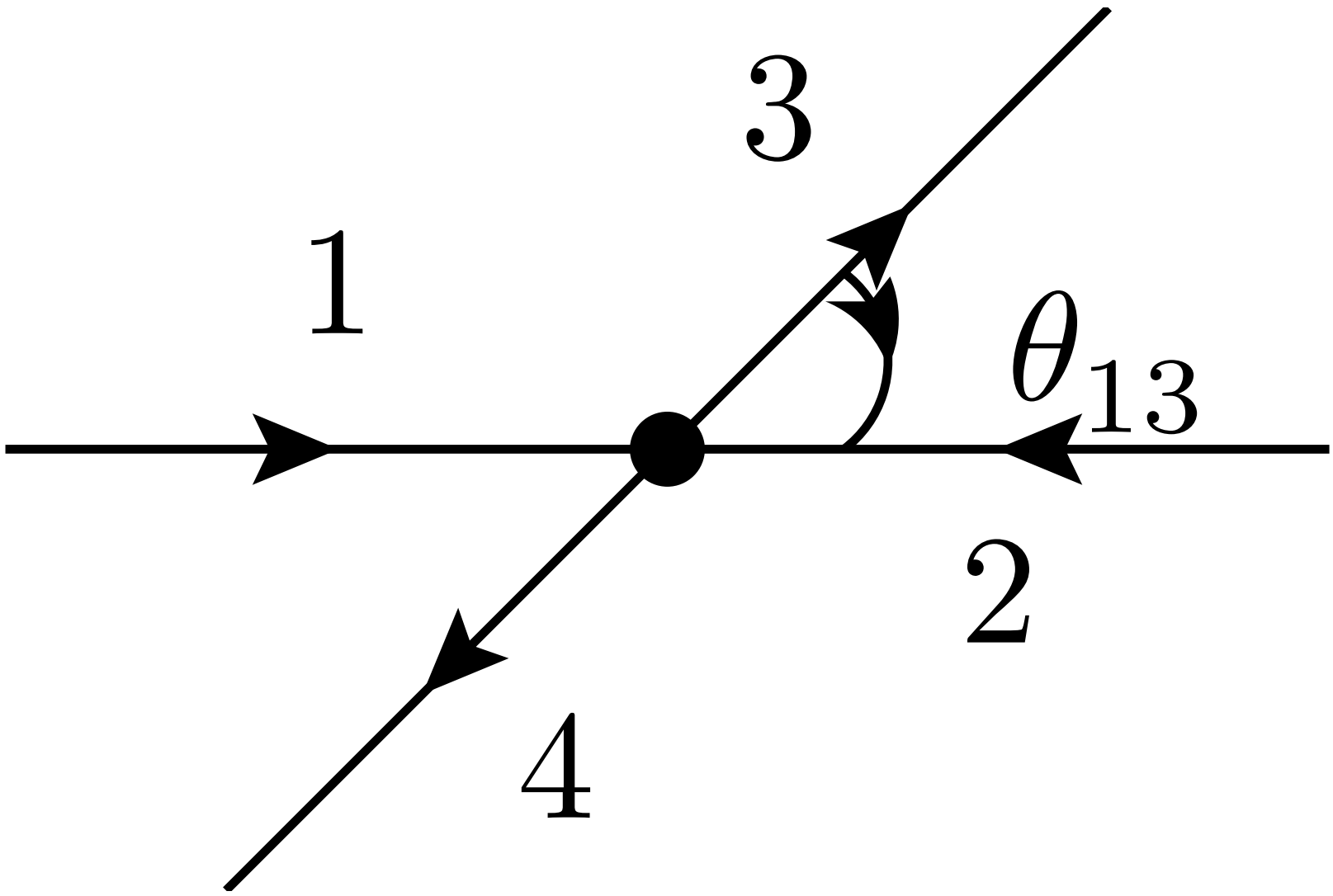
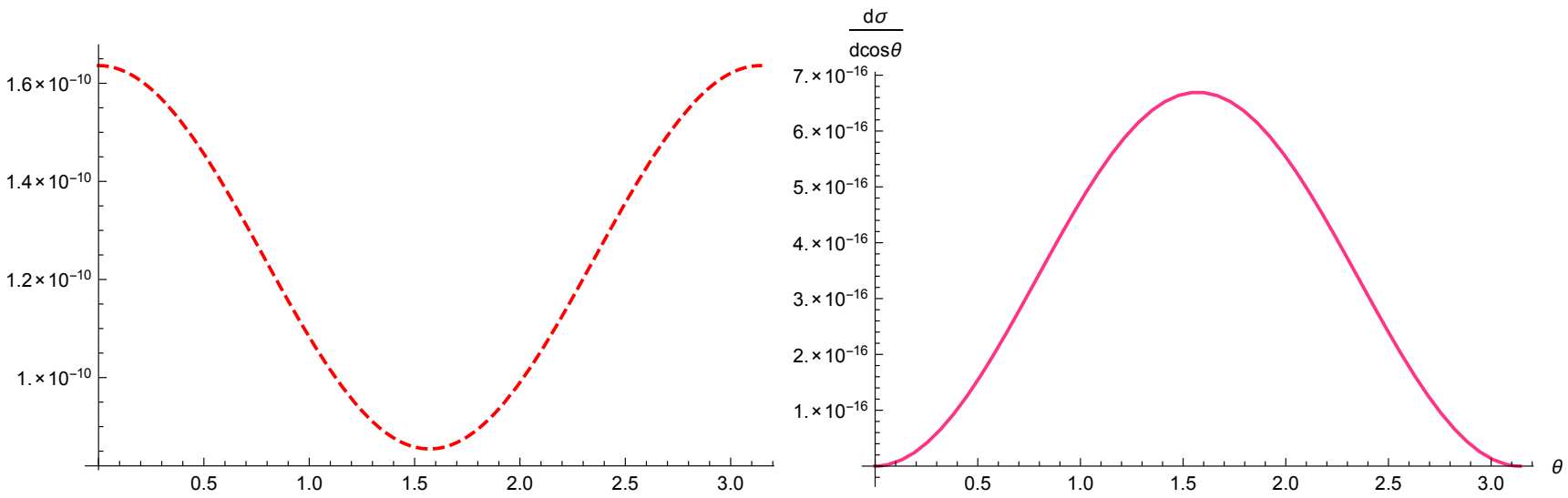
$2 \to 2$ Scattering at Leptonic Collider



A QED Process



(a) $e^+e^- \to \mu^+\mu^-$ (b) $e^+e^- \to \tilde{\mu}^+\tilde{\mu}^-$

Figure: Differential Distribution of the scattered pairs as a function of the angle made with incoming lepton. $\sqrt{s} = 250$ GeV

Challenges at Hadronic Colliders

- Composite Nature of Proton
- Unknown 4-Momenta of Interacting Partons
- Rest Frame of Interaction: Unknown
- Boost of the Rest Frame of Interaction: Unknown
- Axis of the Interacting Pairs: Unknown

Exploiting Advantages of Simulation: Polar Angle of the Scattered Lepton

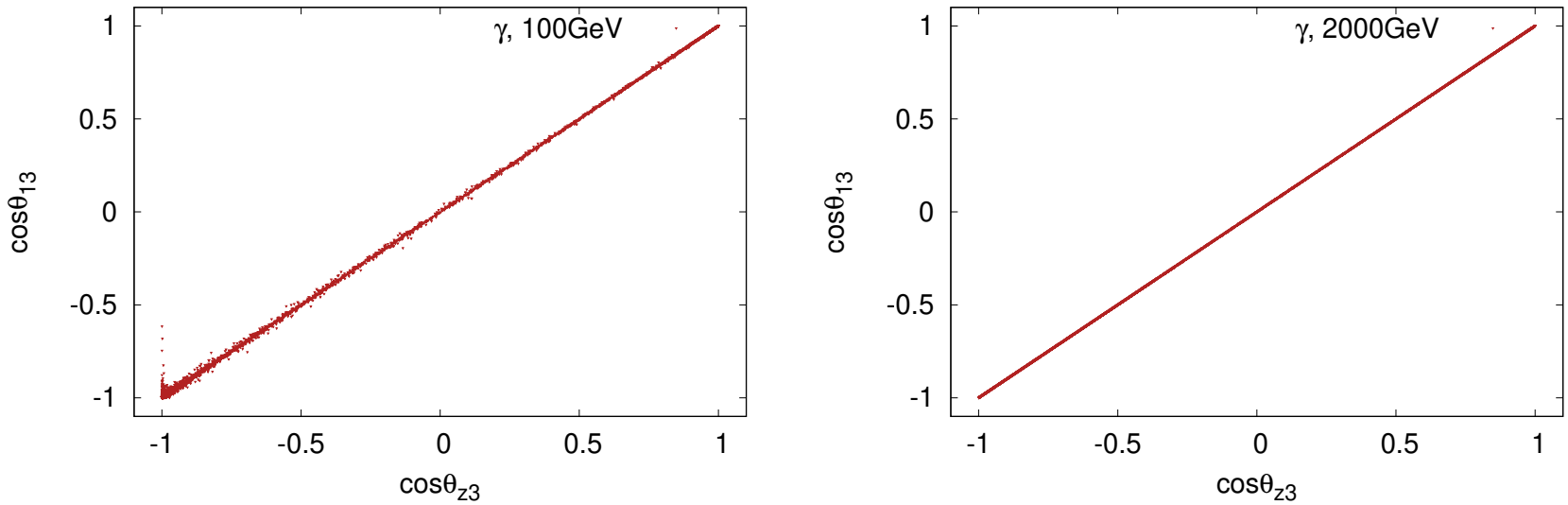


Figure: $pp \to l^+l^-$. Angular Correlations between the Polar Angle of the Scattered Lepton and the Angle made with Interacting Parton from Beam 1. $\sqrt{s} = 8$ TeV

Countering the Boost

- z-Boost Considered
- $2 \rightarrow 2$ Scattering
- Detectable (Reconstructable) Scattered Particles
- Detected: (E_3, p_{z3}), (E_4, p_{z4})
- At Rest Frame: (E_3^*, p_z^*), $(E_4^*, -p_z^*)$

Illustration: Drell-Yan Process at LHC

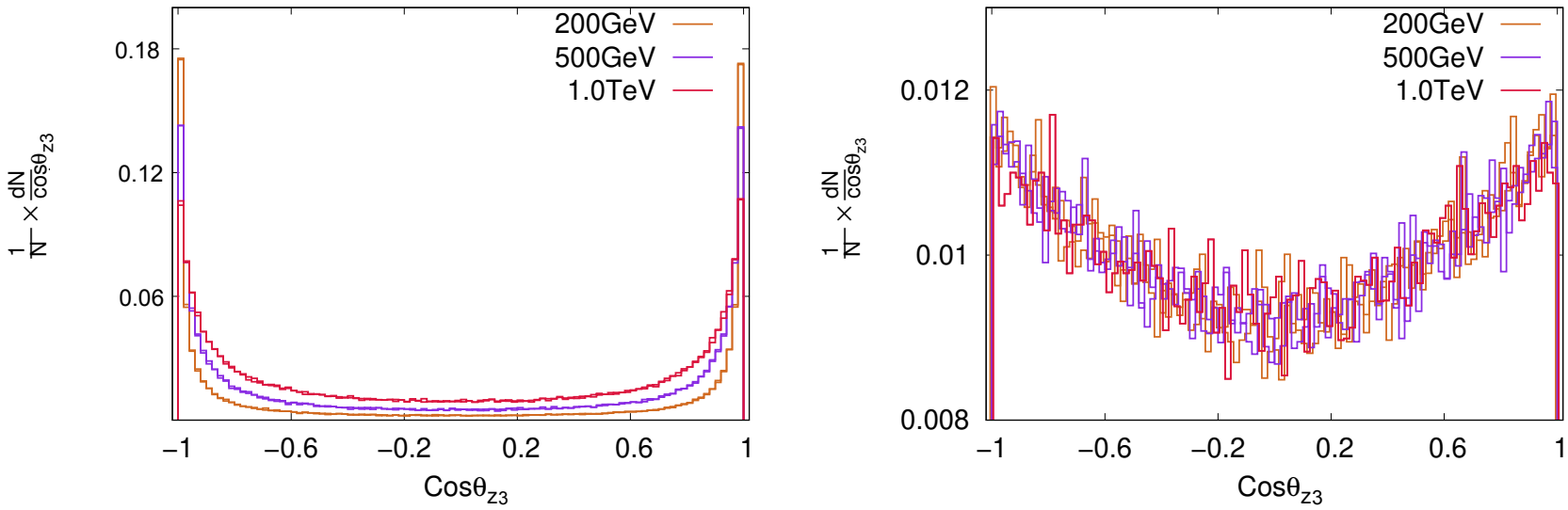


Figure: Differential Distributions of scattered leptons as a function of the Polar Angle. $\sqrt{s} = 14$ TeV

The Leptoquark

- SU(2) Singlet Scalar with Hypercharge $-\frac{2}{3}$
- $\mathcal{L}_{int} = (Y^l\ \bar{Q}_L^c\ (i\sigma^2)\ L_L\ +\ Y^r\ \bar{u}_R^c e_R) LQ\ +\ h.c.$

LQ	Mass	$LQ^{-\frac{1}{3}} \to l^- \bar{u}^c$	$\sigma_{(pp \to LQ\ \overline{LQ})}$ (in fb)	
			14 TeV	100 TeV
BP1	650 GeV	11.6%	191.4	45086.5
BP2	1.5 TeV	97.6%	4.999	1076.7

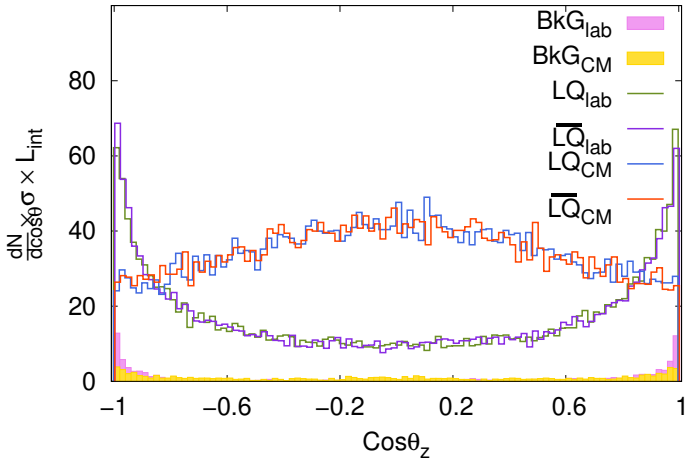
Table: LQ Benchmark points.

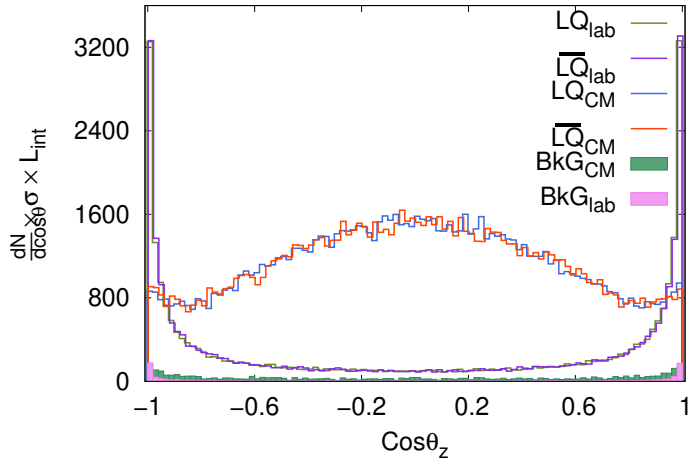
Simulation at LHC

- Detector Coverage: $|\eta| < 2.5$
- Jets: anti-kT, $|p_T| > 20$ GeV, $\Delta R = 0.5$
- Leptons: $|p_T| > 20$ GeV
  - Parton Cleansing: For $\Delta R \leq 0.3$, $p_{T,dep} < 15\%$
  - Jet Isolation: $\Delta R > 0.4$
  - Lepton Isolation: $\Delta R > 0.2$

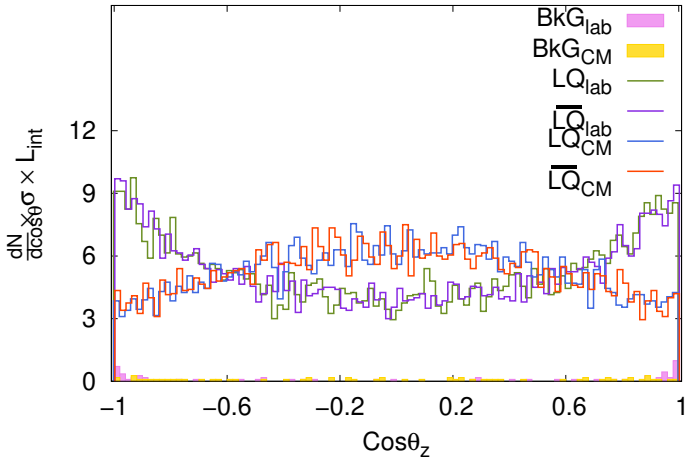
Angular Correlation of Reconstructed Leptoquarks

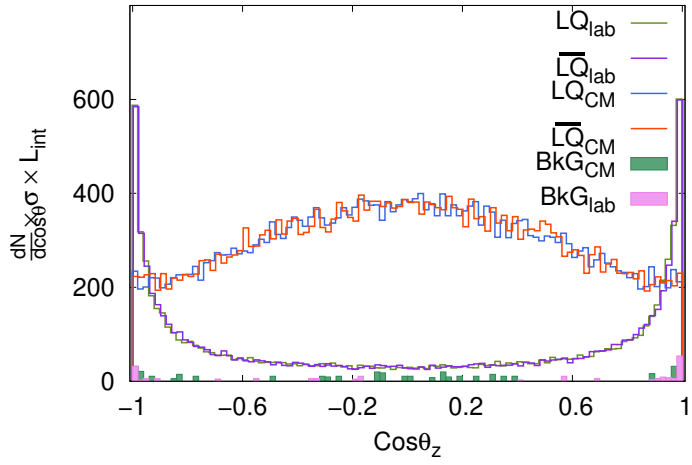
650 Gev





1.5 TeV





14 TeV

100 TeV

The Type-III Seesaw

$$\Sigma = \begin{pmatrix} \frac{N^0}{\sqrt{2}} & N^+ \\ N^- & -\frac{N^0}{\sqrt{2}} \end{pmatrix}$$

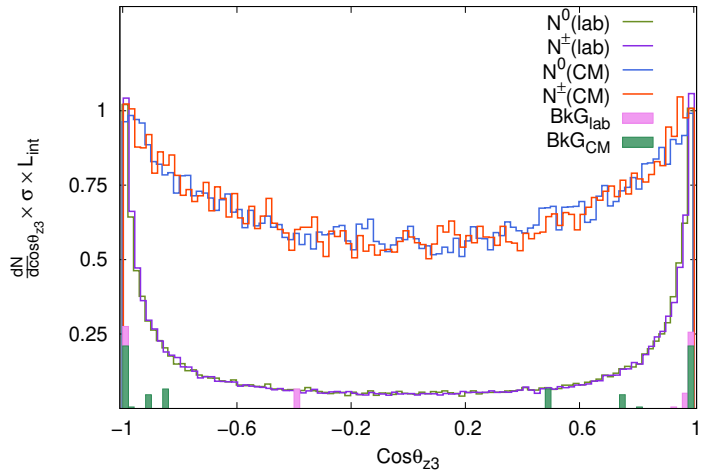
$$\mathcal{L}_{RHN} = Tr(\bar{\Sigma} \not{D} \Sigma) - \frac{1}{2} M_\Sigma Tr\left(\bar{\Sigma}\Sigma^c \ + \ h.c.\right) - Y_{\Sigma l}\left(\tilde{\phi}^\dagger \bar{\Sigma} L \ + \ h.c.\right)$$

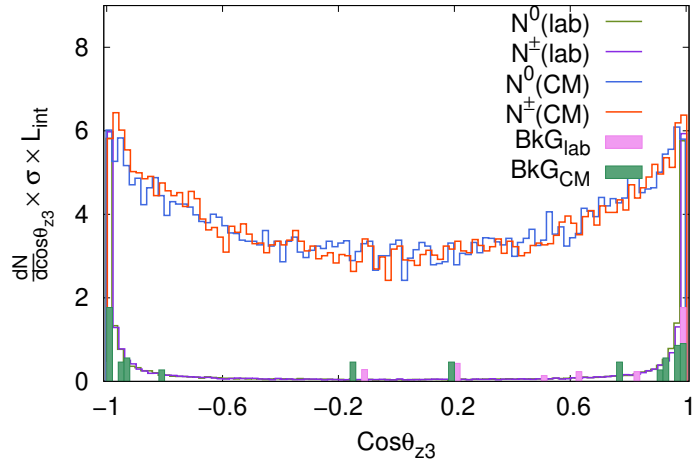
N_R	Mass	$N^0 \to W^\pm l^\mp$	$N^\pm \to Z l^\pm$	$\sigma_{(pp \to N^\pm N^0)}$ (in fb)	
				14 TeV	100 TeV
BP1	750 GeV	50.7%	25.3%	13.9	511.9
BP2	1.2 TeV	50.3%	25.1%	2.42	108.3

Table: *RHN* Benchmark points.

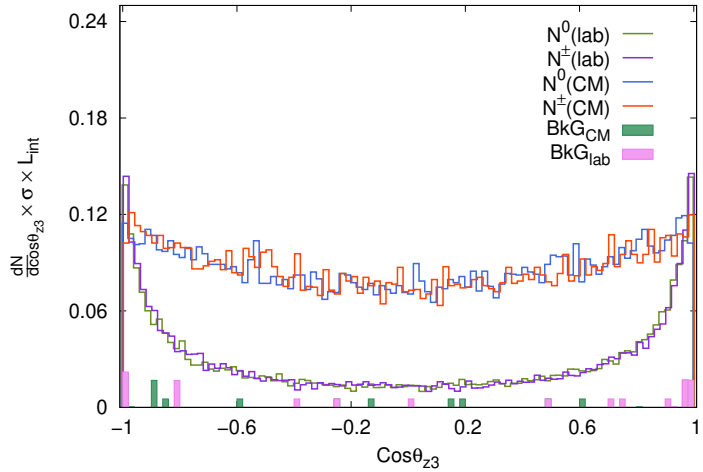
Angular Correlation of Reconstructed RHNs

750 Gev

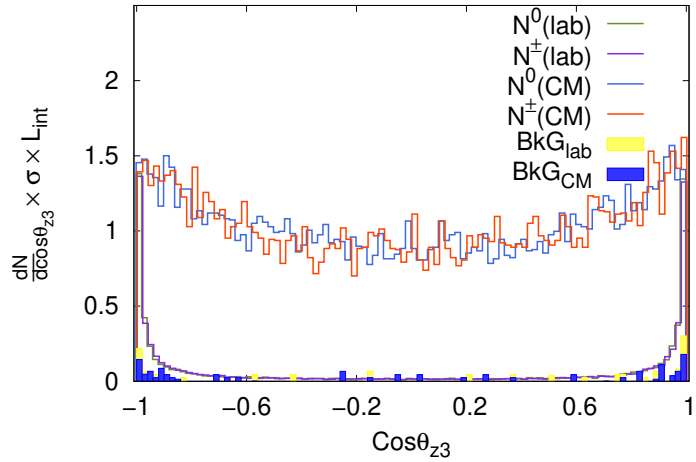




1.2 TeV



14 TeV



100 TeV


Thank
you!