

# Measurement of Dijet Angular Distributions at $\sqrt{s} = 1.96 \text{ TeV}$ and Searches for Quark Compositeness and Extra Spatial Dimensions

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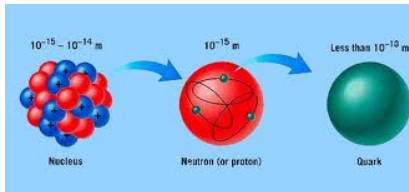
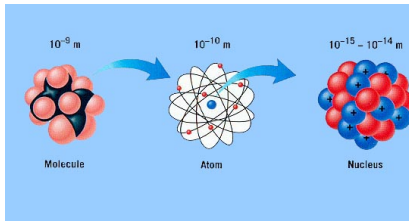
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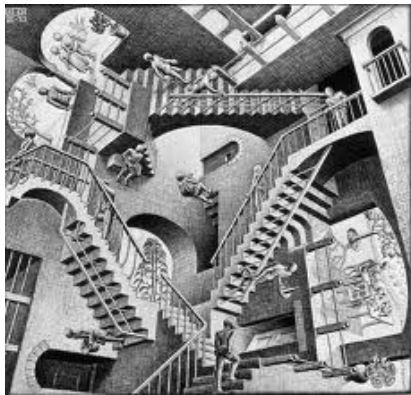
# A Little bit of History...

- From Atoms, to Nucleons, to Quarks... Is it the end of the story?



# A Little bit of History.....

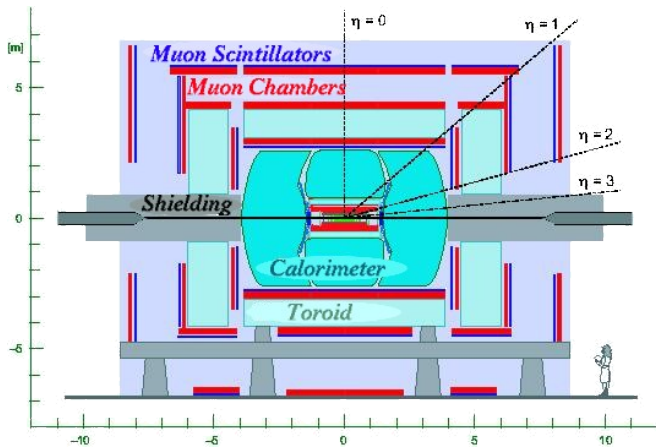
- Do we really understand the space we live in? Are we satisfied with 3D space?



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# D0 Detector

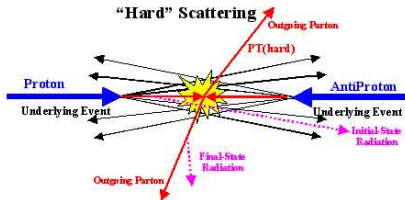


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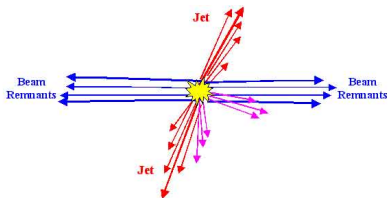
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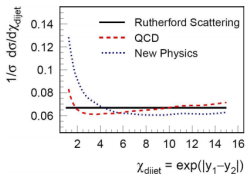




$$\sqrt{s} = 1.96 \text{ TeV}$$



- At large momentum transfers, dijet production has the largest cross section of all processes at a hadron collider and therefore directly probes the highest energy regime.
- It can be used to test the SM at previously unexplored small distance scales and to search for signals predicted by new physics models.
- In QCD the distribution of dijets shows small but noticeable deviations from Rutherford scattering, an excess at large angles from the beam axis would be a sign of new physics process, such as **quark compositeness** or the existence of **extra spatial dimensions**.



- Jets are defined by Run II midpoint cone jet algorithm with a cone radius of  $R = \sqrt{(\Delta y)^2 + (\Delta \phi)^2} = 0.7$

where  $y = 0.5 \ln\left(\frac{1+\beta \cos\theta}{1-\beta \cos\theta}\right)$  is the rapidity of the jet with

$$\beta = \frac{|\vec{p}|}{E}$$

- Distributions are measured in 10 regions of dijet invariant mass  $M_{jj}$  in the variable

$$\chi_{dijet} = e^{|y_1 - y_2|}$$

because Rutherford scattering angle is independent of  $\chi_{dijet}$ .

- in massless  $2 \rightarrow 2$  scattering limit  $\chi_{dijet} = \frac{1+\cos\theta^*}{1-\cos\theta^*}$
- the phase space of this analysis is defined by  $|y_{jet}| < 2.4$



# Background and instrumental effects corrections

- Data sample used  $L = 0.7fb^{-1}$
- The jets energy is corrected for showers and multiple  $p\bar{p}$  interactions
- Difference in electron and photon and real jet showers is used to suppress the background
- Simulated events generated with PYTHIA are subjected to a simulation of the D0 detector response and reweighted according to  $M_{jj}$  distribution data
- Corrections for unreconstructed muons and neutrinos are included.

⇒ correction factors for differential cross section :  $0.9 \sim 1.0$   
⇒ fraction of background events : less than 0.1%





# New Physics Models

Quark Compositeness : quarks could be made of other particles

Parameters : energy scale  $\Lambda$ ; sign of the interference term  $\eta$

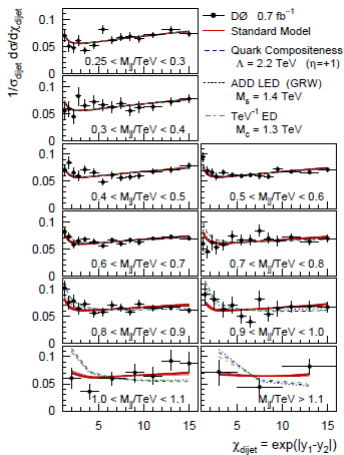
ADD LED : extra spatial dimensions exist in which gravity is allowed to propagate

Parameters : effective Planck scale,  $M_S$ ; number  $n$  of extra dimensions (HLZ model)

$TeV^{-1}$  ED : extra dimensions exist at the  $TeV^{-1}$  scale

Parameters : compactification scale,  $M_C$





- Normalized differential cross sections in dijet compared to standard model predictions and to the predictions of various new physics models
- New physics models change shape in  $\chi_{dijet}$  at higher  $M_{dijet}$
- The higher the parameters in the new physics models, the closer the new models to SM



## Expected and observed 95% C.L. limits (in units of TeV) on various new physics models

Model (parameter)	Prior flat in NP Lagrangian		Prior flat in NP x-section		$\Delta\chi^2 = 3.84$ criterion	
	Observed	Expected	Observed	Expected	Observed	Expected
<i>QC</i> ( $\Lambda$ )						
$\eta = +1$	2.91	3.06	2.76	2.84	2.80	2.92
$\eta = -1$	2.97	3.06	2.75	2.82	2.82	2.96
$\text{TeV}^{-1}$ <i>ED</i> ( $M_C$ )	1.73	1.67	1.60	1.55	1.66	1.59
<i>ADD LED</i> ( $M_S$ )						
<i>GRW</i>	1.53	1.67	1.47	1.59	1.49	1.66
<i>HLZ</i> $n = 3$	1.81	1.98	1.75	1.89	1.77	1.97
<i>HLZ</i> $n = 4$	1.53	1.67	1.47	1.59	1.49	1.66
<i>HLZ</i> $n = 5$	1.38	1.51	1.33	1.43	1.35	1.50
<i>HLZ</i> $n = 6$	1.28	1.40	1.24	1.34	1.25	1.39
<i>HLZ</i> $n = 7$	1.21	1.33	1.17	1.26	1.19	1.32



- Similar analysis did in CMS and ATLAS (arXiv:1202.5535v1, arXiv:1103.3864v1)
- More strict limits were set as the energy LHC could reach is higher.
- Still no sign of new physics



- First measurement of dijet angular distributions in Run II of the Fermilab Tevatron Collider
- A model independent search set limits on quark compositeness, ADD large extra dimensions, and  $TeV^{-1}$  extra dimensions models
- For the  $TeV^{-1}$  extra dimensions model: first direct search at a collider
- **No indication of new physics detected**



# Thank you!



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