The inequality:

$$\frac{1}{4}\left(T^m{}_m - T_\mu{}^\mu\right)^{loc.} - T_3\,\rho_3^{loc} \geq 0.$$

We shall examine to leading order in α'.

p-brane: $T_\alpha{}^\beta = -T_p\,\delta_\alpha{}^\beta\,\delta(x_\perp)$

α ↓ tangential; $x_\perp$ ↓ $\perp$ direction

$$T_m{}^m = -T_p\,(p-3)\,\delta(x_\perp)$$

$$T_\mu{}^\mu = -T_p \cdot 4 \cdot \delta(x_\perp)$$

$$\left(T_m{}^m - T_\mu{}^\mu\right) = T_p\,(7-p)\,\delta(x_\perp) \quad > 0 \text{ for } p \leq 7$$

$T_p > 0$

Only these are used

$\rho_3^{loc} = 0$ except for $p=3$,

$$p=3: \quad \frac{1}{4}T_3 \cdot 4\,\delta(x_\perp) \mp T_3\,\delta(x_\perp) \geq 0.$$

$-$: D3; $+$: $\overline{D3}$

$= 0$ for D3.

Inequality is violated for

O5: $T_5 < 0$ $\qquad$ $\overline{O3}$ $\quad T_3 < 0$

So far we have discussed compactification of IIB in presence of localized sources and fluxes in general terms.

$\rightarrow$ Requires first solving eqs. for τ and metric in absence of fluxes.

Assume no $H^{(3)}, F^{(3)} \Rightarrow$ no 5-brane source, total # of 3-branes = 0.

Assume no localized 3-brane source either.

There can be localized 7-branes/O7-planes.

① Orientifolds ② F-theory.

Type I: IIB/Ω $\hookrightarrow$ world-sheet parity.

Ω: $B_{MN} \rightarrow -B_{MN}$, $C^{(0)} \rightarrow -C^{(0)}$, $C^{(2)} \rightarrow C^{(2)}$,

$C^{(4)} \rightarrow -C^{(4)}$

~~Combine~~ Another $\mathbb{Z}_2$ symmetry $(-1)^{F_L}$

$\rightarrow$ changes sign of all R-sector states on left.

G_{MN}, B_{MN}, Φ invariant.

$C^{(0)}$, $C^{(2)}$, $C^{(4)}$ changes sign

$RR \to -RR$.

Consider IIB on $S^1 \leftarrow$ IIA on $\tilde{S}^1$

	$G_{\mu\nu}$		$G_{\mu\nu}$
even $\leftarrow$	$G_{9\mu}$	$\leftrightarrow$	$B_{9\mu} \to$ even
odd $\leftarrow$	$B_{9\mu}$	$\leftrightarrow$	$G_{9\mu} \to$ odd.
	Ω	$\leftrightarrow$	$\Omega \cdot \mathcal{I}_1$
			$\mathcal{I}_1 \to x^9 \to -x^9$
			$B \to -B$, $G \to G$, $\phi \to \Phi$

Confirmed in RR sector.

odd $\leftarrow$	$C^{(0)}$	$\leftrightarrow$	$C^{(1)}_9$ odd since $x^9 \to -x^9$
even $\leftarrow$	$C^{(2)}_{\mu\nu}$	$\leftrightarrow$	$C^{(3)}_{9\mu\nu} \to$ even since $C^{(3)} \to -C^{(3)}$, $x^9 \to -x^9$
$\leftarrow$	$C^{(2)}_{9\mu}$	$\leftrightarrow$	$C^{(1)}_{\mu} \to$ even

etc.

IIB on $S^1 \times S^1$ = IIA on $\tilde{S}^1 \times S^1$ = IIB on $\tilde{S}^1 \times \tilde{S}^1$

even $\leftarrow$ G_{89} $\qquad\qquad$ $C^{(2)}_{89}$ G_{89}

~~even~~ odd $\leftarrow$ B_{89} $\qquad\qquad$ B_{89}

even $\leftarrow$ $G_{9\mu}$ $\qquad\qquad$ $B_{9\mu}$

even $\leftarrow$ $G_{8\mu}$ $\qquad\qquad$ $B_{8\mu}$

odd $\leftarrow$ $B_{9\mu}$ $\qquad\qquad$ $G_{9\mu}$

odd $\leftarrow$ $B_{8\mu}$ $\qquad\qquad$ $G_{8\mu}$

$\tilde{x}^8 \to -\tilde{x}^8$, $\tilde{x}^9 \to -\tilde{x}^9$: $\mathcal{I}_2$

B_{89} odd $\Rightarrow$ Ω

even. $C^{(2)}_{89}$ $\longleftrightarrow$ $C^{(0)}$

$\downarrow$

even.

odd under $\mathcal{I}_2 \cdot \Omega$

Need $(-1)^{F_L} \cdot \Omega \cdot \mathcal{I}_2$

Ex. check that all other fields transform correctly if we postulate that Ω maps to $(-1)^{F_L} \cdot \Omega \cdot \mathcal{I}_2$

$(-1)^{F_L} \cdot \Omega$ leaves $C^{(0)}$ & Φ invariant

$\Rightarrow \tau$ is invariant

$$\begin{pmatrix} B^{(2)} \\ C^{(2)} \end{pmatrix} \to -\begin{pmatrix} B^{(2)} \\ C^{(2)} \end{pmatrix}$$

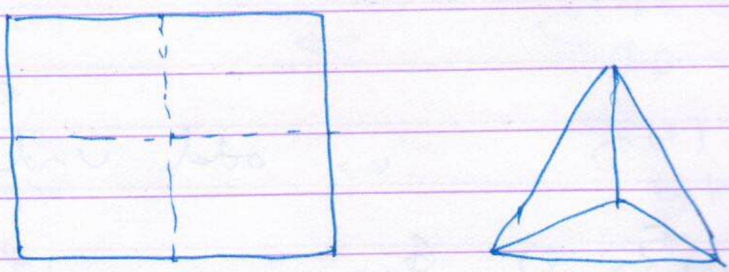
$\Rightarrow$ Equivalent to $SL(2,\mathbb{Z})$ trs:

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix} = \begin{pmatrix} -1 & 0 \\ 0 & -1 \end{pmatrix}$$

$g_2 : (x^8, x^9) \to (-x^8, -x^9)$,

(x^8, x^9) has period 2π each.

Fixed points : $(0,0), (0,\pi), (\pi,0), (\pi,\pi)$.



As we move around a closed circle around a vertex, fields get transformed by $(-1)^{F_L} \cdot \Omega$

~~variations~~

D-branes: IIB/Ω has O9-plane carrying -ve D-brane charge.

$\Rightarrow$ Needs to be cancelled by 16 D-branes & their images.

$\Rightarrow SO(32)$.

~~Ou~~ In T-dual picture we have 16 D7-branes.

$\hookrightarrow$ along $x^0, \ldots x^7$

$\rightarrow$ placed at points on the tetrahedron.

Vertices carry -4 units of D7-brane charge.

Total D-brane charge $= 0$.

If 4 D-branes are placed at each vertex we shall have no net D7-charge even locally.

$\Rightarrow$ No source for $C^{(0)}$! $\tau =$ constant.

Gauge group $(SO(8))^4 \rightarrow$ in IIB/Ω we switch on Wilson lines.

What happens when we pull the D7's away from O7-planes?

Localized sources $\Rightarrow$ τ not constant

First approximation: Ignore backreaction on the metric, treating it as flat.

$$ds^2 = |dz|^2$$

τ - eq: $\partial_z \partial_{\bar{z}} \tau = 0$. Localized sources.

$C^{(0)} \to C^{(0)} + 1$ as we go anti-clockwise around a D7.

$$\Rightarrow \tau = \frac{1}{2\pi i} \ln (z - z_0) + c$$

Location of D7.

$$\overline{D7} \Rightarrow \tau = \frac{1}{2\pi i} \ln (\bar{z} - \bar{z}_0) + c$$

For preserving SUSY we only consider D7.

O7 carries -4 unit of D7 charge

$$\tau = -\frac{4}{2\pi i}\ln(z-z_0) + c.$$

1 O7 + 4 D7:

$$\tau = -\frac{4}{2\pi i}\ln(z-z_0) + \sum_{i=1}^{4}\frac{1}{2\pi i}\ln(z-z_i) + \tau_0$$

Note: As $z \to z_i$, $\tau \to \frac{1}{i}\times(-\infty) = i\infty$

$\Downarrow$

$C^{(0)} + ie^{-\Phi}$ $\Leftrightarrow$ $\Phi \to -\infty$.

weak coupling

As $z \to z_0$. $\tau \to -i\infty$

$\Downarrow$

not sensible

Solution breaks down near the core of O7.

Later we shall see how to resolve this problem.

Monodromy: $\tau \to \tau + 1$ around D7.

$SL(2,\mathbb{Z})$ transform $\begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix}$

$\tau \to \tau - 4$ together with $\begin{pmatrix} -1 & 0 \\ 0 & -1 \end{pmatrix}$

$\Rightarrow SL(2,\mathbb{Z})$ trs $\begin{pmatrix} -1 & 0 \\ 0 & -1 \end{pmatrix}\begin{pmatrix} 1 & -4 \\ 0 & 1 \end{pmatrix} = \begin{pmatrix} -1 & 4 \\ 0 & -1 \end{pmatrix}$

This can be generalized to IIB on $\mathcal{M}$ to get 4-d compactification (can ~~~~ take to be CY_3)

7 Suppose $\mathcal{M}$ has a $\mathbb{Z}_2$ isometry g_2 with fixed 4-planes.

Near the fixed plane we have

① tangential complex coordinate w_1, w_2

② transverse complex coordinate z

$g_2 : z \to -z, \ (w_1, w_2) \to (w_1, w_2)$

Take quotient by $(-1)^{F_L} \cdot \Omega \cdot g_2$

Note: Ω: exchanges two susy trs.

$(-1)^{F_L} \cdot \Omega$: produces at most some extra sign acting on susy trs

$\Rightarrow$ One linear combination survives.

$\mathcal{N} = 1$ SUSY in $D = 4$