Transitions in minimally supersymmetric theories of quantum gravity

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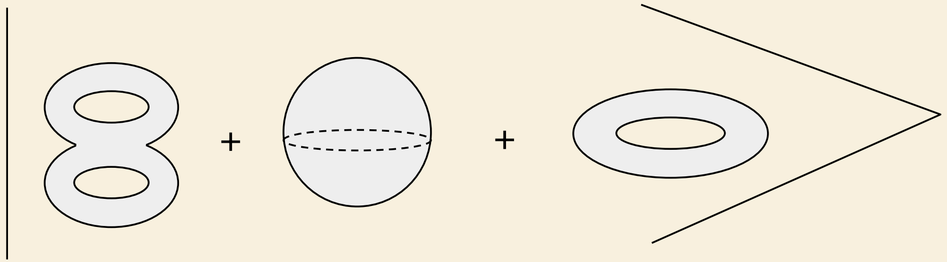
Work in progress [25xx. xxxx]

w/ Lorenzo Paoloni and Max Wiesner

Workshop on Quantum Gravity and Strings. Corfu25

Motivation

Topological transitions are expected in quantum gravity



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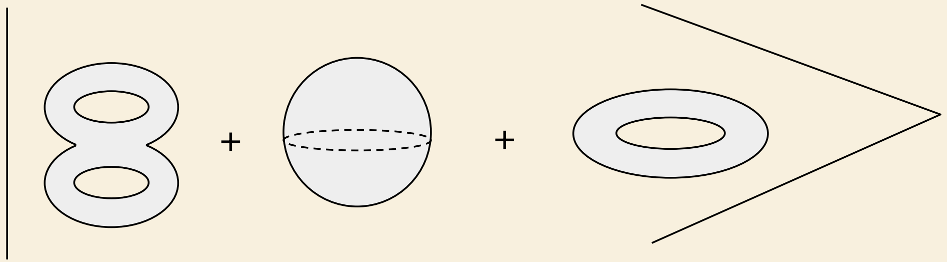
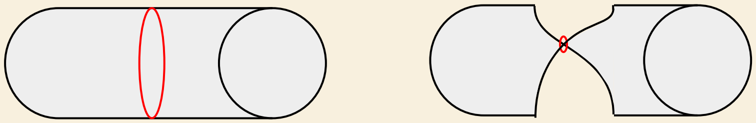


They are well understood in theories with extended SUSY

Exact moduli spaces or mirror symmetry help!

Good control over shrinkable cycles

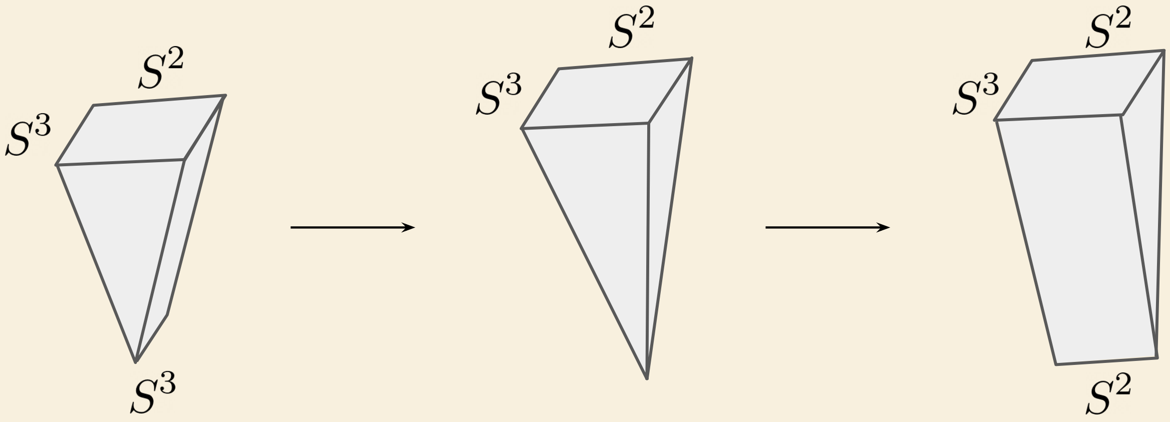


Prime example: Conifold transitions in 4d $\mathcal{N}=2$

[Strominger 95]
[Greene, Morrison, Strominger 95]
[Greene, Morrison, Vafa 96]

Coulomb branch

Higgs branch



Complex structure ⟷ Kähler

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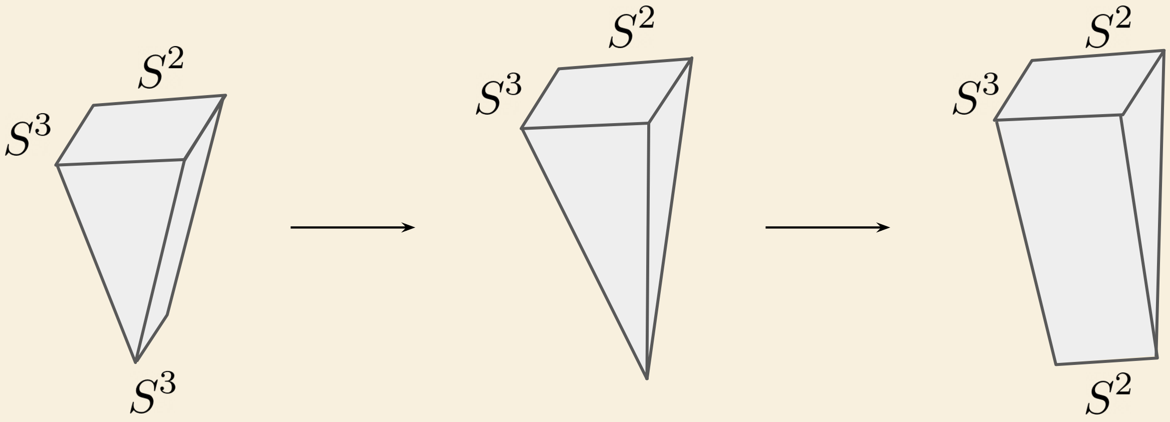

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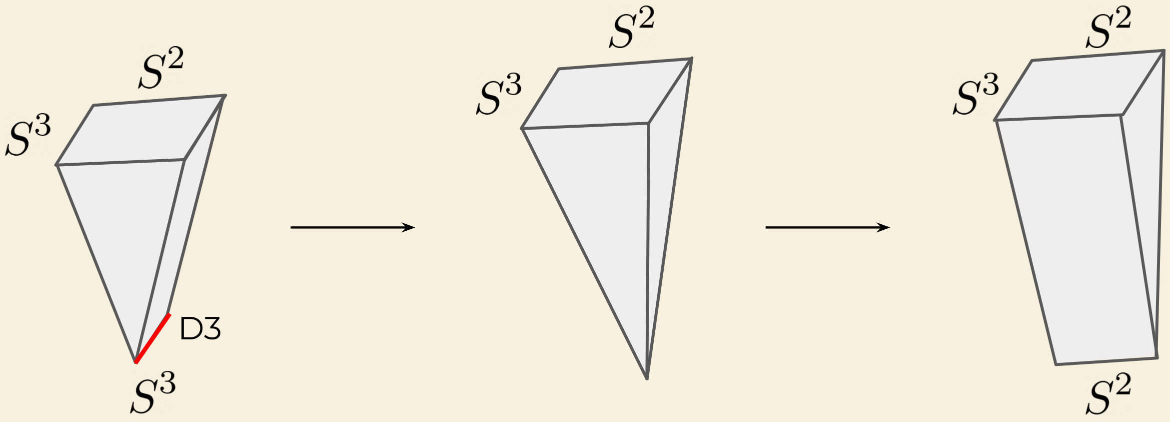

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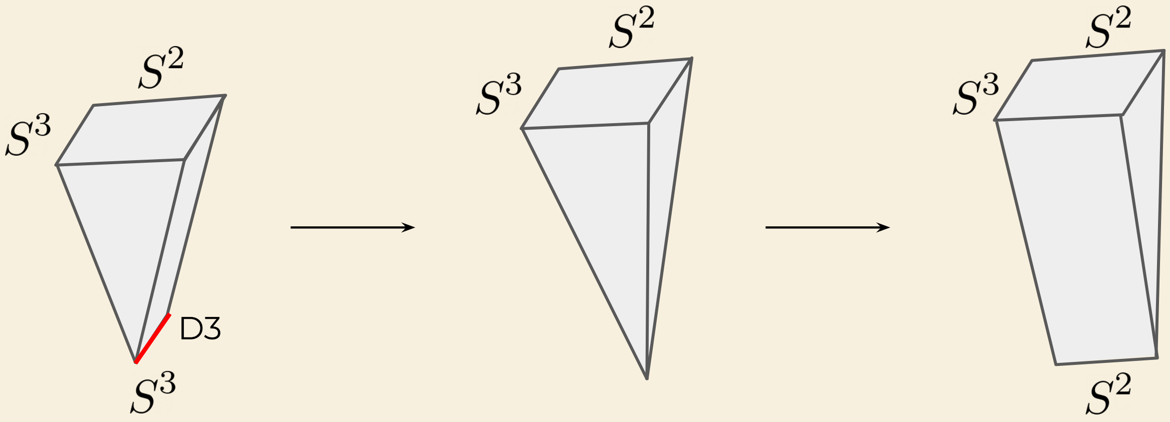

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$$A_\mu^{m=0} \quad + \quad (4,0)_H^{D3} \quad \longleftrightarrow \quad A_\mu^{m \neq 0} = (5,3)$$

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- Topological transitions usually require non-perturbative effects.
- Well understood and trustable for theories with extended SUSY
- Clear separation between Higgs and Coulomb branch

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Goal

- Use minimally supersymmetric set ups.
- First step: Look for sectors with enhanced supersymmetry.
- Use examples with extra SUSY as a guideline.

Warm up 6d $\mathcal{N} = (1,0)$

[Morrison, Vafa 96']

F-theory on CY3

$$\mathcal{E} \hookrightarrow X_3 \to \mathbb{F}_n$$

$\longleftrightarrow$

Heterotic E8XE8 on K3

$$24 = (12 - n) + (12 + n)$$

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Also: [Aldazabal, Font, Ibañez, Quevedo 96]
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$\mathbb{T}_2 \leftrightarrow \mathbb{T}_0$, $\mathbb{T}_2 \subset \mathbb{T}_0$ Share the same moduli space!

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Heterotic transition is extremal and not obvious! Remove instanton numbers from the E8s

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A degree 24 hypersurface in $\mathbb{P}_{1,1,2,8,12}$ can be viewed

$$\mathcal{E} \hookrightarrow X_3 \to \mathbb{F}_2\,, \qquad n_V = 0\,, n_T = 1\,, n_H = 243$$

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Missing a hyper

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$$y_1 y_2 + y_3^2 = 0$$

Blowing down a (-2)-curve in $\mathbb{F}_2$

$$\downarrow$$

$$y_1 y_2 + y_3^2 = \psi_{n.p}\, y_4$$

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Smooth transition

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The vicinity of h locally realized enhanced supersymmetry [Witten 96]

A D3 on h
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The tensor + hyper form a $\mathcal{N} = (2,0)$ matter mult. in 6d

↳ $\psi_{n.p}$ is predicted by susy enhancement

Lessons:

1. Transition well understood in F-theory. Heterotic transition goes through extremal points

2. Local enhanced supersymmetry requires an additional hypermultiplet in $\mathbb{F}_2$. This allows us to transition to $\mathbb{F}_0$

SUSY enhancement	🤝	Topological transitions

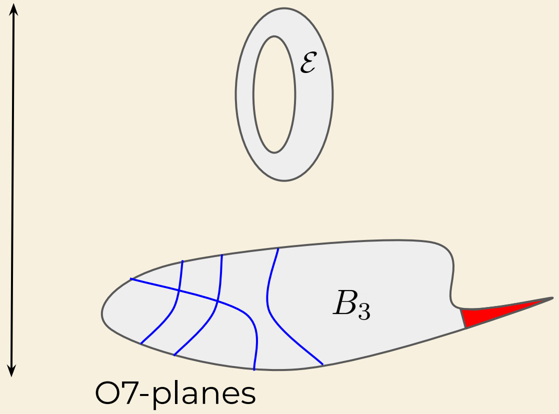
Guideline: Mimic the 6d F-theory strategy:

$$\bar{K}_{\mathbb{F}_2} \cdot_{\mathbb{F}_2} h = 0 \longrightarrow \text{Enhanced susy subsector}$$

Flop transitions in 4d

We follow same idea as in 6d F-theory

F-theory on X_4



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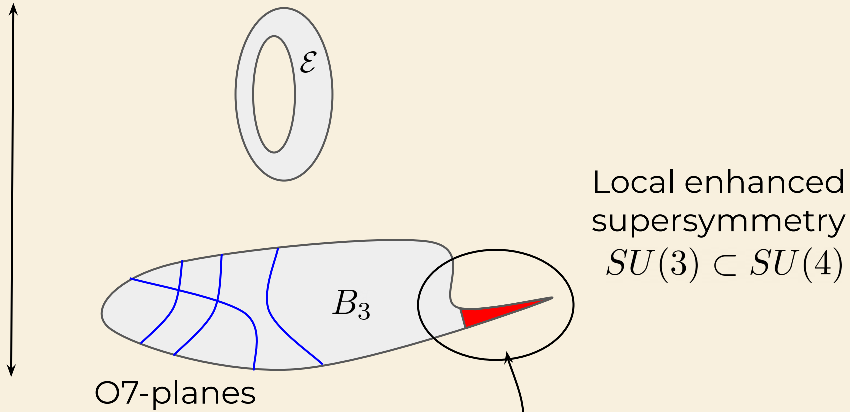

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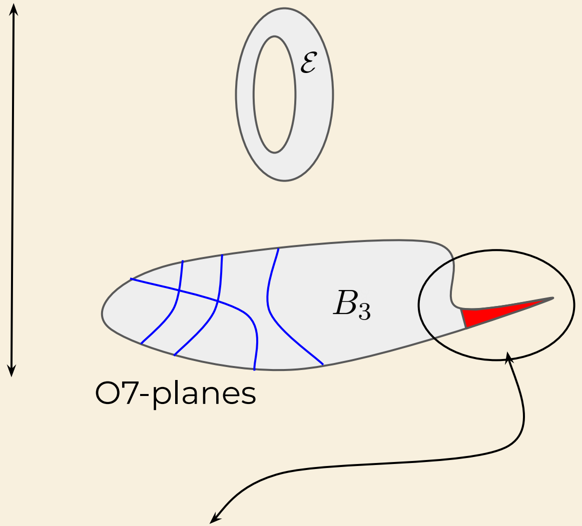


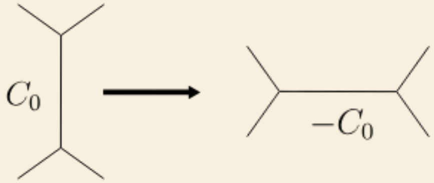
Local enhanced supersymmetry
$SU(3) \subset SU(4)$

Assume a curve with,

$$\bar{K}_{B_3} \cdot C_0 = 0$$

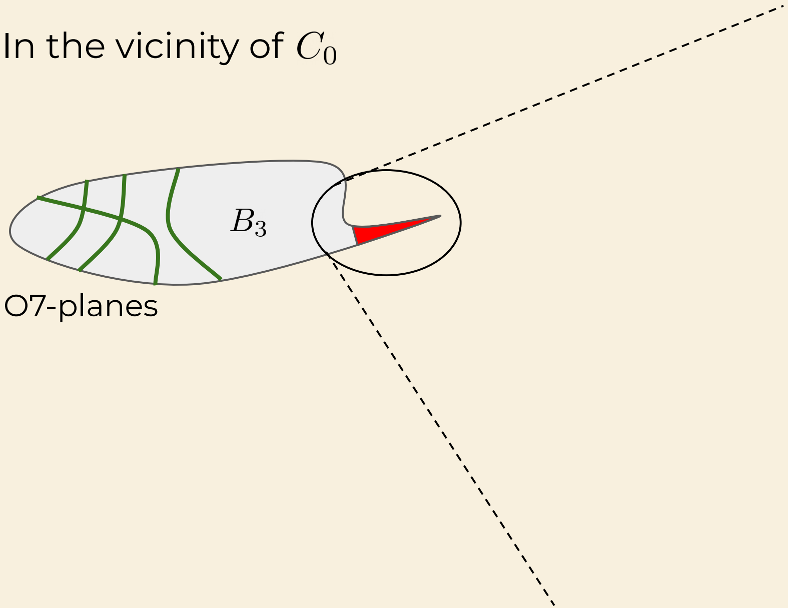
plus floppable

$$\mathcal{N}_{C_0/B_3} = \mathcal{O}(-1) \oplus \mathcal{O}(-1)$$



Take the type IIB limit: $T^2 \hookrightarrow X_4 \to X_3$

In the vicinity of C_0



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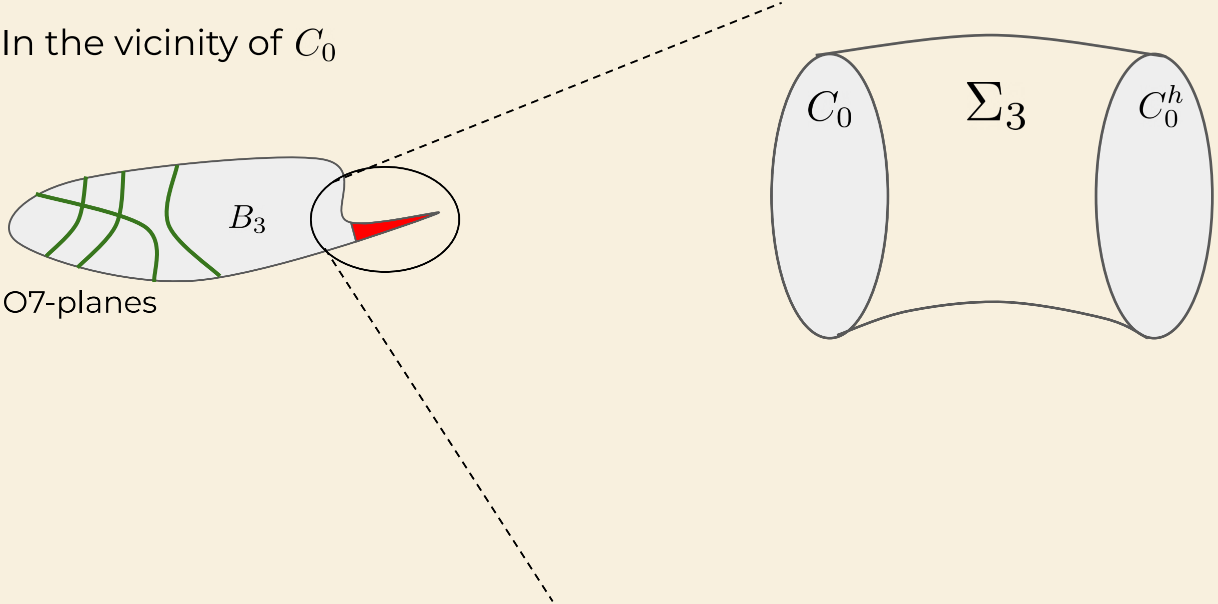

Conifold setup

Higgs branch

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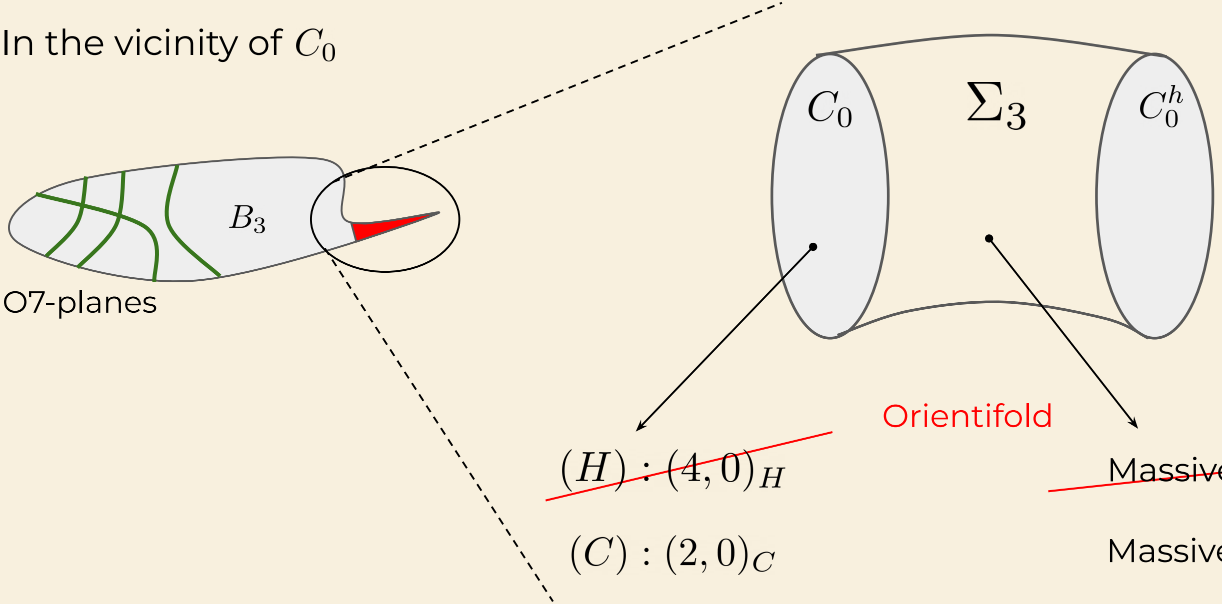

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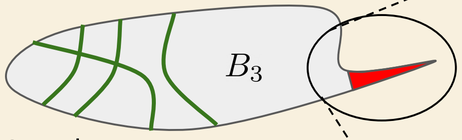
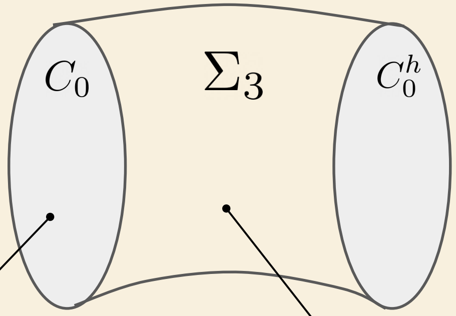


O7-planes



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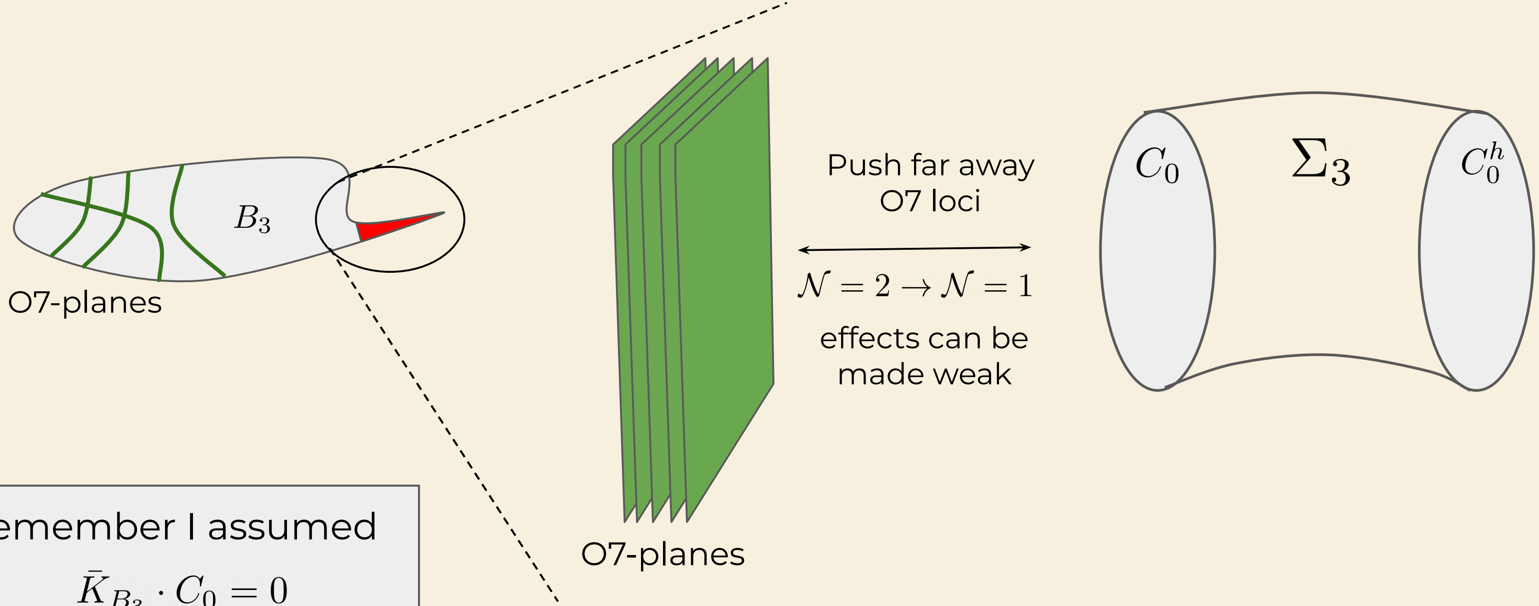

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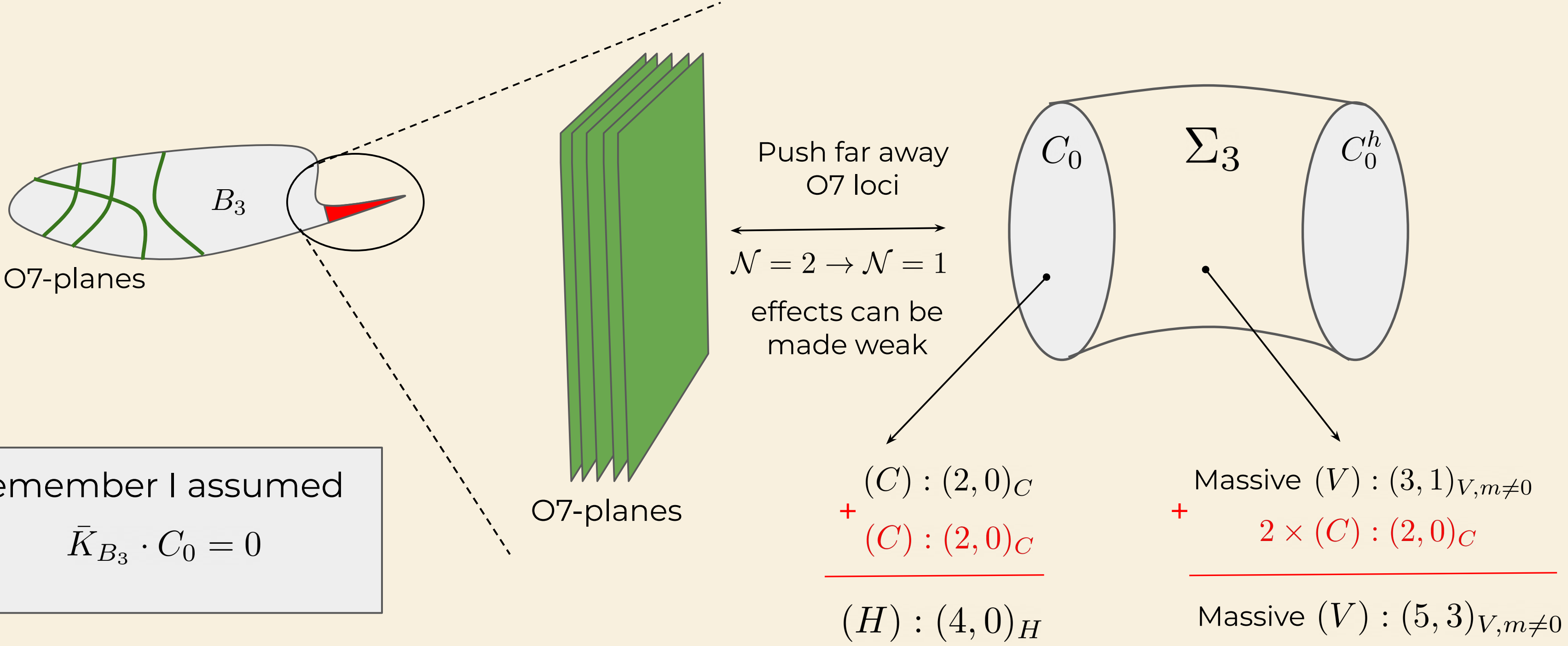

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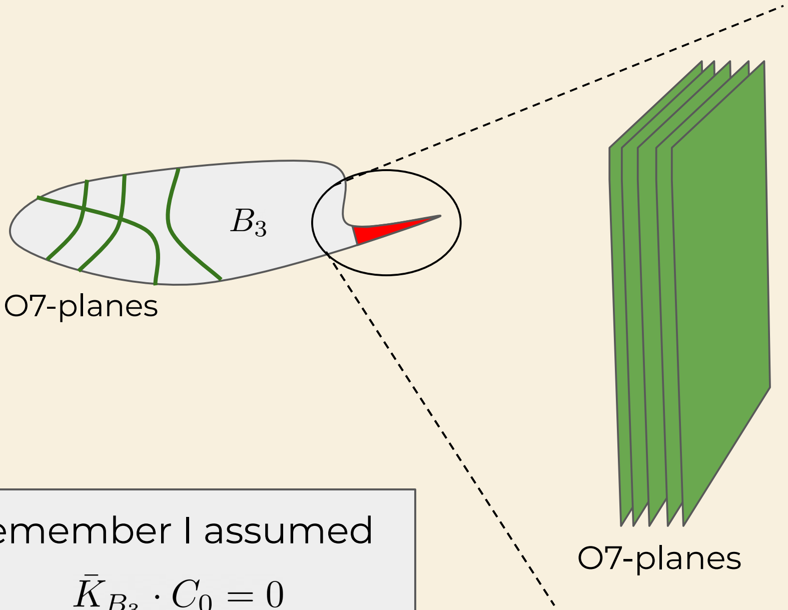
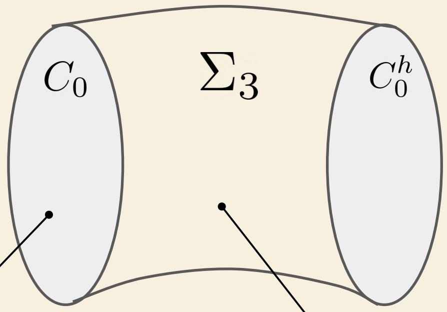


Push far away
O7 loci

$\mathcal{N}=2 \to \mathcal{N}=1$

effects can be
made weak



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$+$ $2 \times (C) : (2,0)_C$

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As in 6d, they are related to a n.p deformation

Back to F-theory:

Non-perturbative phase structure of C_0:

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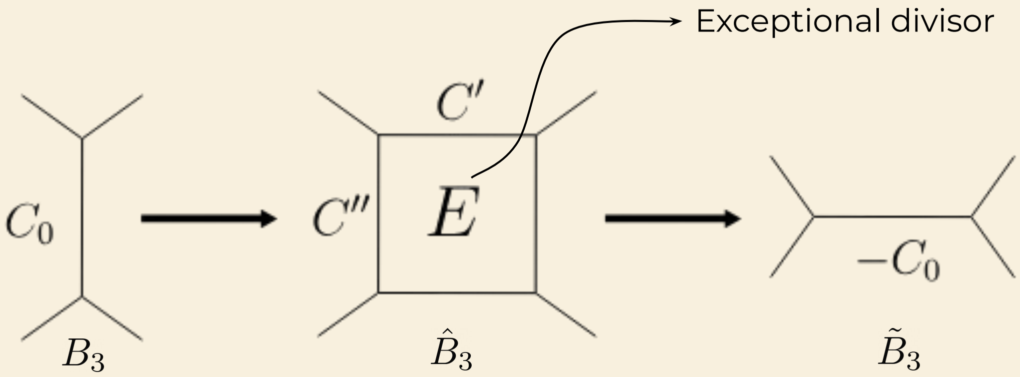

Natural n.p deformation candidate: birational factorization of the flop → Similar to 6d F-theory

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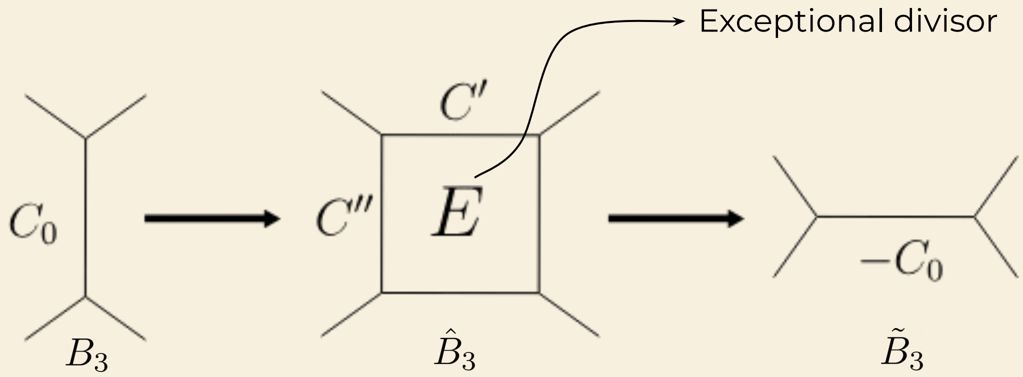

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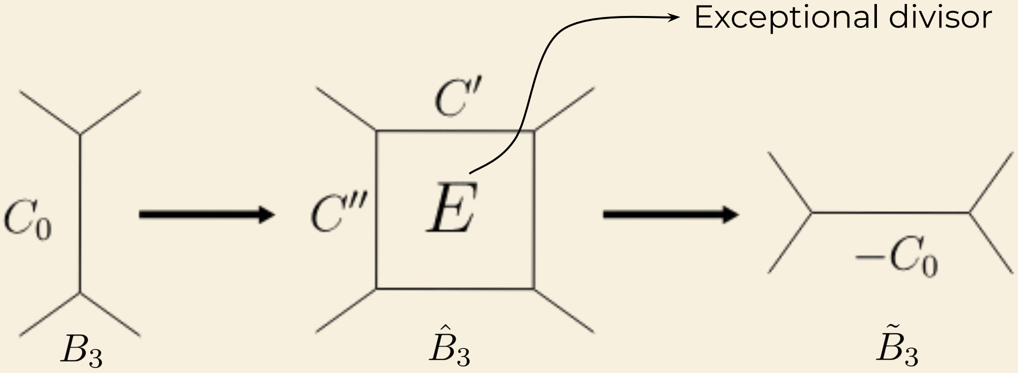

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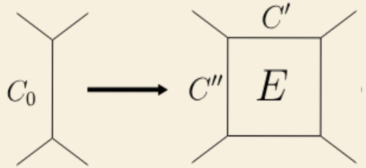
Similar to 6d heterotic

Invisible from perturbative type IIB on CY orientifolds. Since violates the CY condition

New geometric light states

$$T_E = \frac{1}{2g_s}\int_E J_{\hat{B}_3}^2 + i\int_E C_4 \longrightarrow \text{Extra chiral}$$



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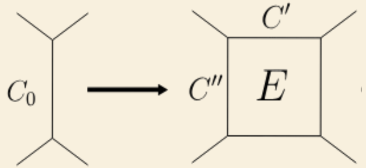
The Euler characteristic changes



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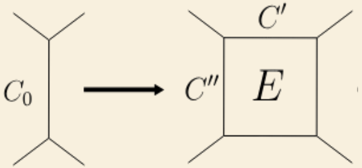

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We find

$$\delta h^{1,1} = \delta h^{2,1} = 1 \qquad \delta h^{3,1} = -124$$

Local data

Two extra chirals from the
local geometry deformation

$$(T_E) : (2,0)_C \quad + \quad (\chi_0) : (2,0)_C$$

Still missing one!

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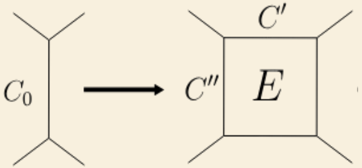

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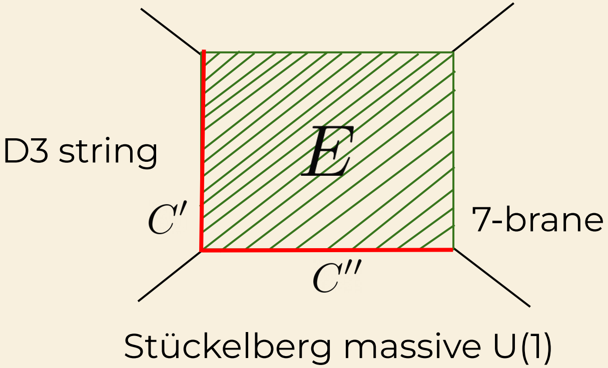
Global data

Along with a change in the number of D3-branes

Decoupled sector!

More in [25xx. xxxx]

Missing charged chiral (like in conifold)



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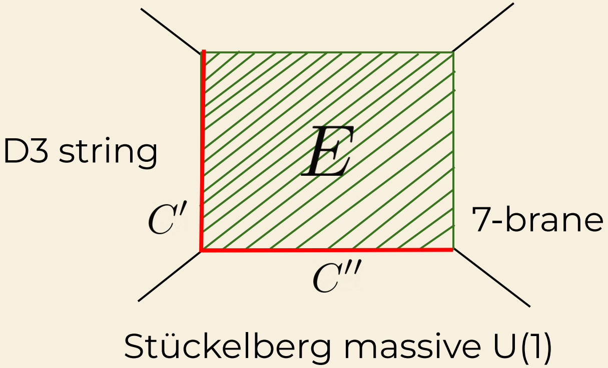
The excitations of the string carry U(1) charge

$$E \cdot_{\hat{B}_3} C'' = 1$$



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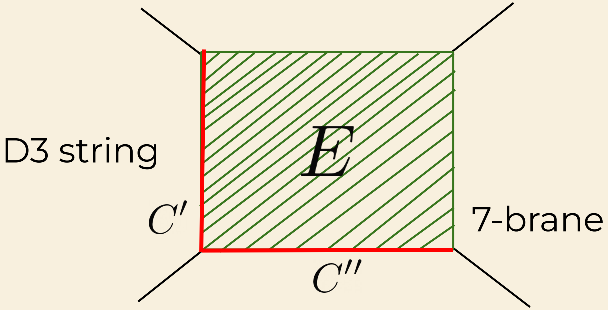

Stückelberg massive U(1)

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The string tension

$$\left.\frac{T_{\mathrm{S}''}}{M_s^2}\right|_{\mathrm{pert.}} = \left| t'' + \frac{i}{2} \right|$$

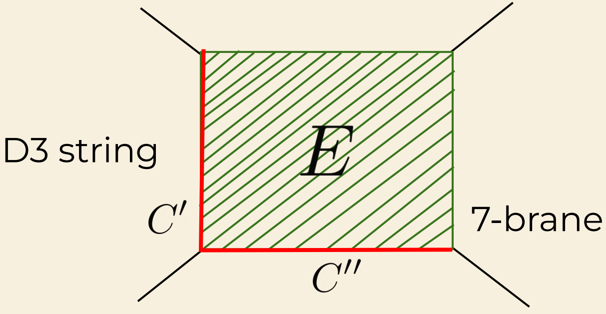
Axion turned on

$$\bar{K}_{\hat{B}_3} \cdot C'' \neq 0$$

Like heterotic gauge enhancements states

Finite tension ⟷ Finitely many massless excitation

Missing charged chiral (like in conifold)



Stückelberg massive U(1)

The excitations of the string carry U(1) charge

$$E \cdot_{\hat{B}_3} C'' = 1$$

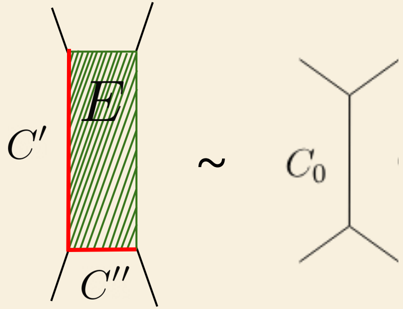
The string tension

$$\left.\frac{T_{\mathrm{S}''}}{M_s^2}\right|_{\text{pert.}} = \left| t'' + \frac{i}{2} \right|$$

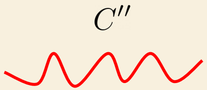
Axion turned on

$$\bar{K}_{\hat{B}_3} \cdot C'' \neq 0$$

There has to be a light charged state even though full quantization is not known!



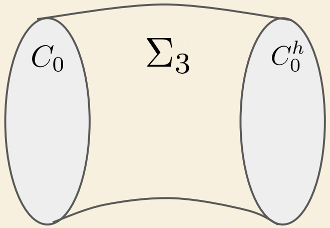
Chiral comes from the string



Like heterotic gauge enhancements states

Finite tension ⟷ Finitely many massless excitation

Summary: multiplets and origin

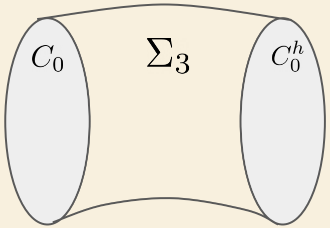


$(C) : (2,0)_C$

Massive $(V) : (3,1)_{V,m\neq 0}$

Due to local enhanced SUSY we must to fill out N=2 supermultiplets

Summary: multiplets and origin



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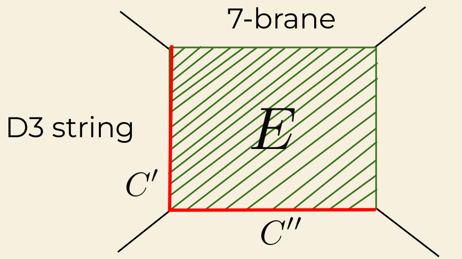


Stückelberg massive U(1)

$(C) : (2,0)_C$
+
New divisor $(C) : (2,0)_C$

$(H) : (4,0)_H$

Massive $(V) : (3,1)_{V,m\neq 0}$
+
$(C) : (2,0)_C$ Extra $h^{2,1}$
$(C) : (2,0)_C$ D3 string exc.

Massive $(V) : (5,3)_{V,m\neq 0}$

Conclusions

- Topological transitions are well understood in theories with extended supersymmetry.
- As a first step, we search for sectors with enhanced supersymmetry in minimally supersymmetric theories.
- Our guiding principle is

$$\bar{K}_{B_3} \cdot C_0 = 0$$

- While perturbative type IIB does not capture all the physics, F-theory does provide the necessary degrees of freedom to fill out N=2 supermultiplets

More in [25xx. xxxx]

- Enhanced SUSY in the c.s moduli space/conifold transitions
- Global SUSY breaking effects are discussed
- The heterotic duality of this F-theory setup

Ευχαριστώ πολύ

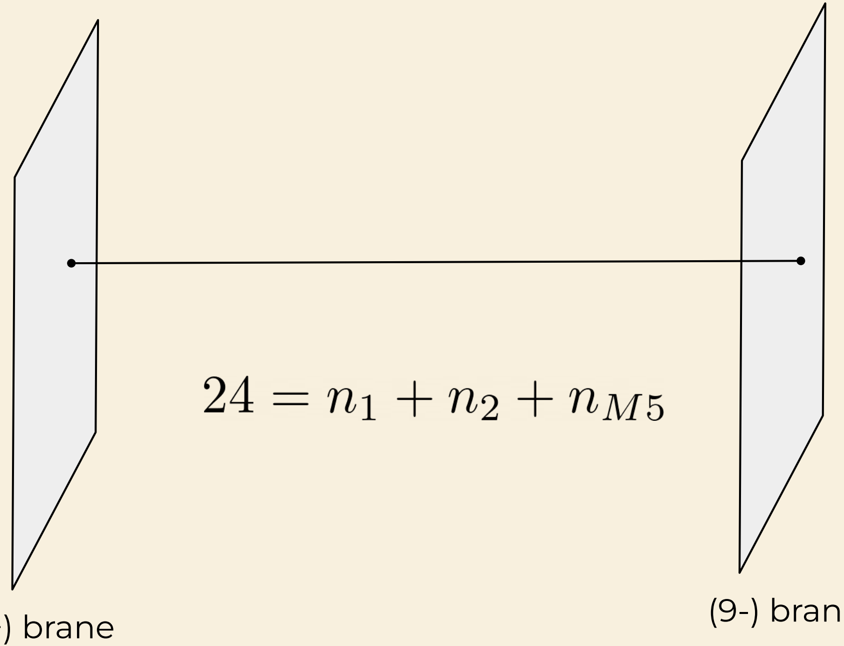
BACK UP SLIDES

Heterotic point of view

$$\mathbb{T}_2 \leftrightarrow \mathbb{T}_0$$

$$(12, 12) \longleftrightarrow (10, 14)$$

From Heterotic-M-theory on $K3 \times S^1/\mathbb{Z}_2$



$$24 = n_1 + n_2 + n_{M5}$$

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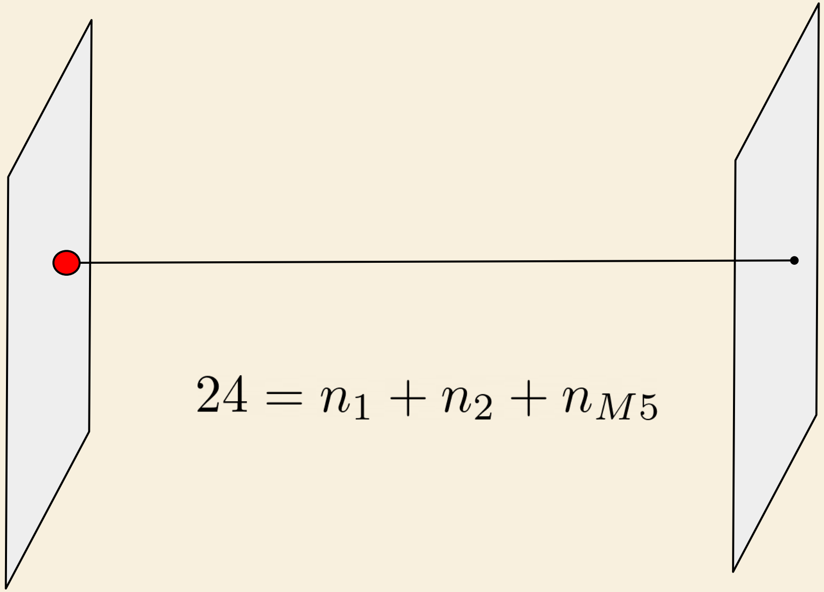

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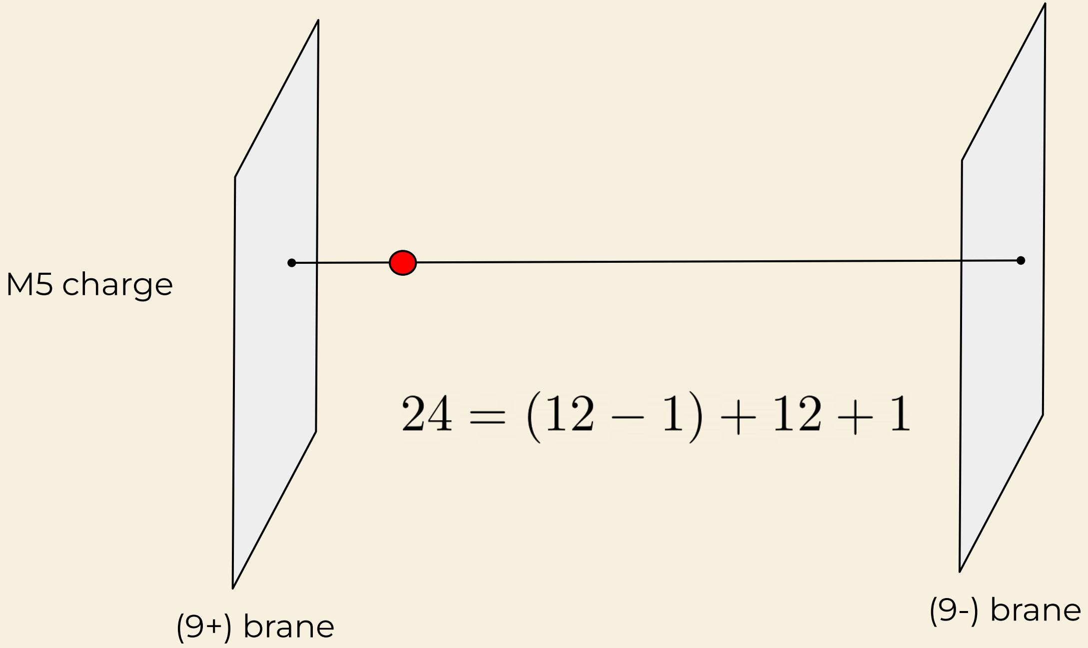

$$24 = (12 - 1) + 12 + 1$$

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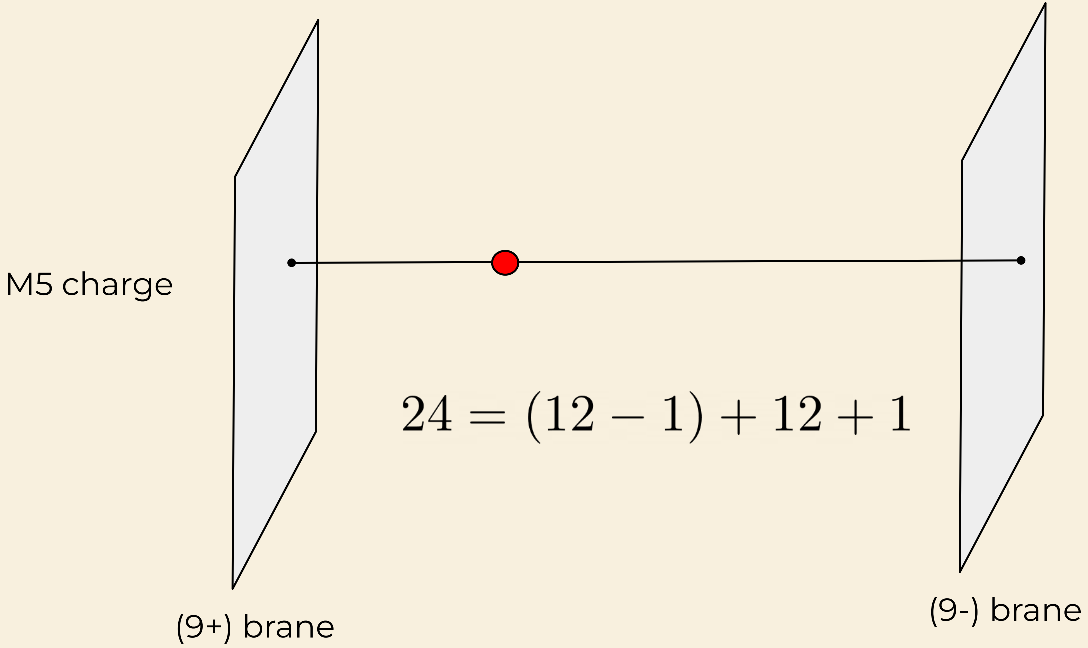

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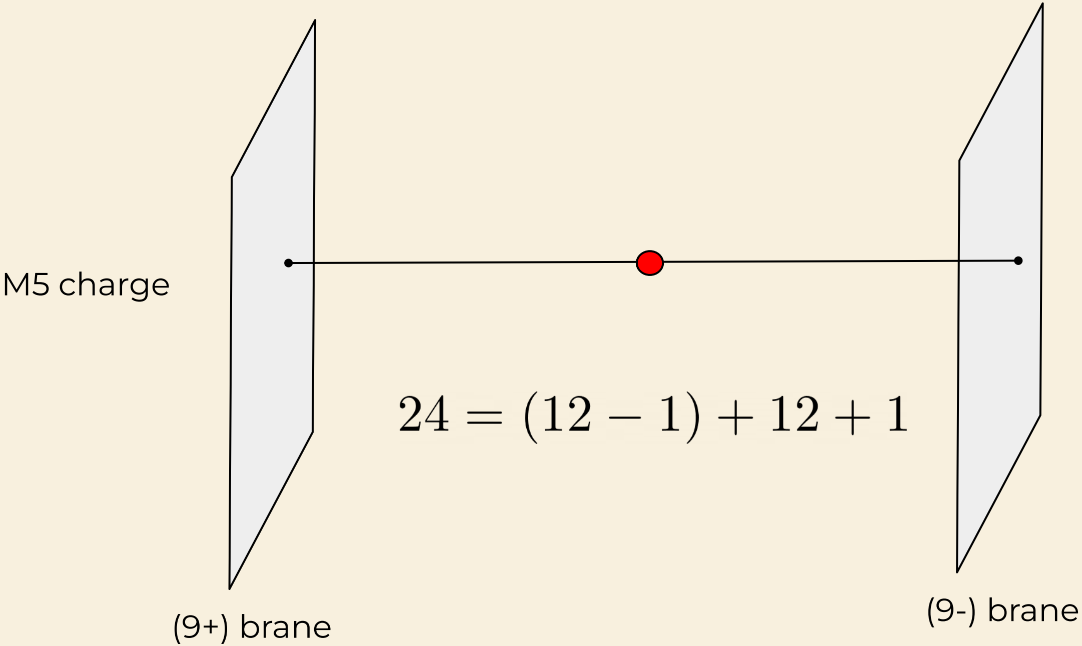

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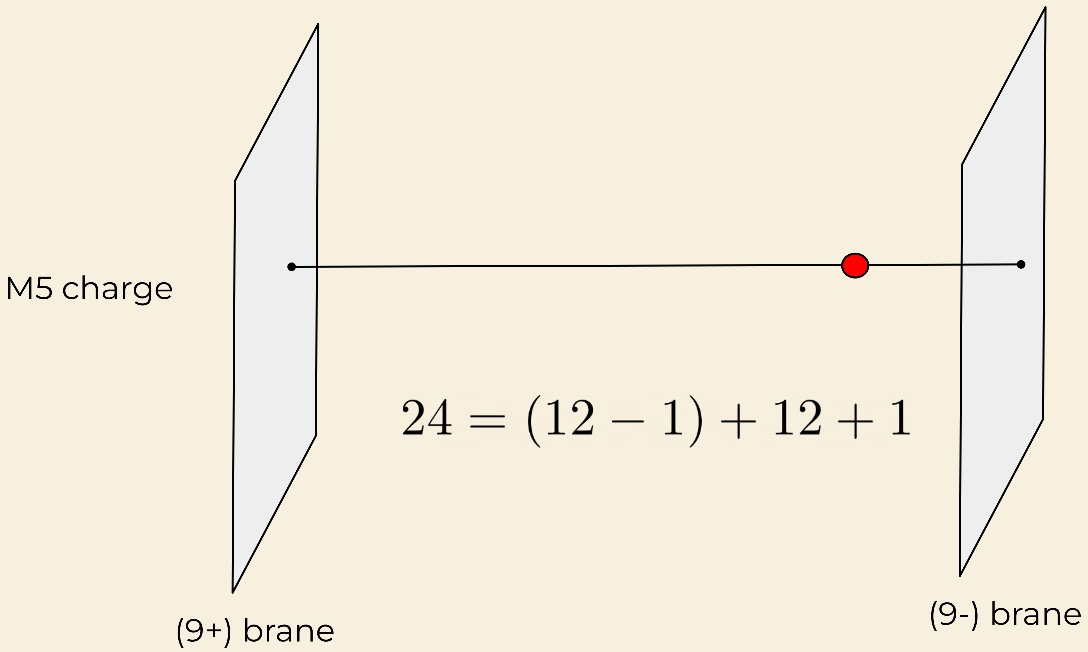

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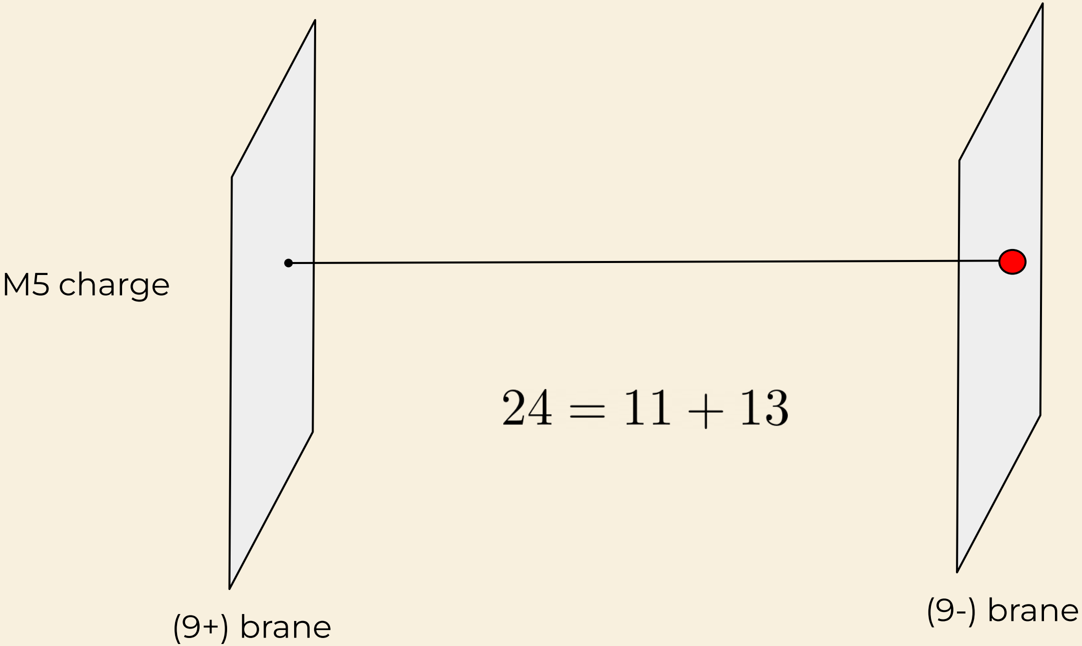

$$24 = 11 + 13$$

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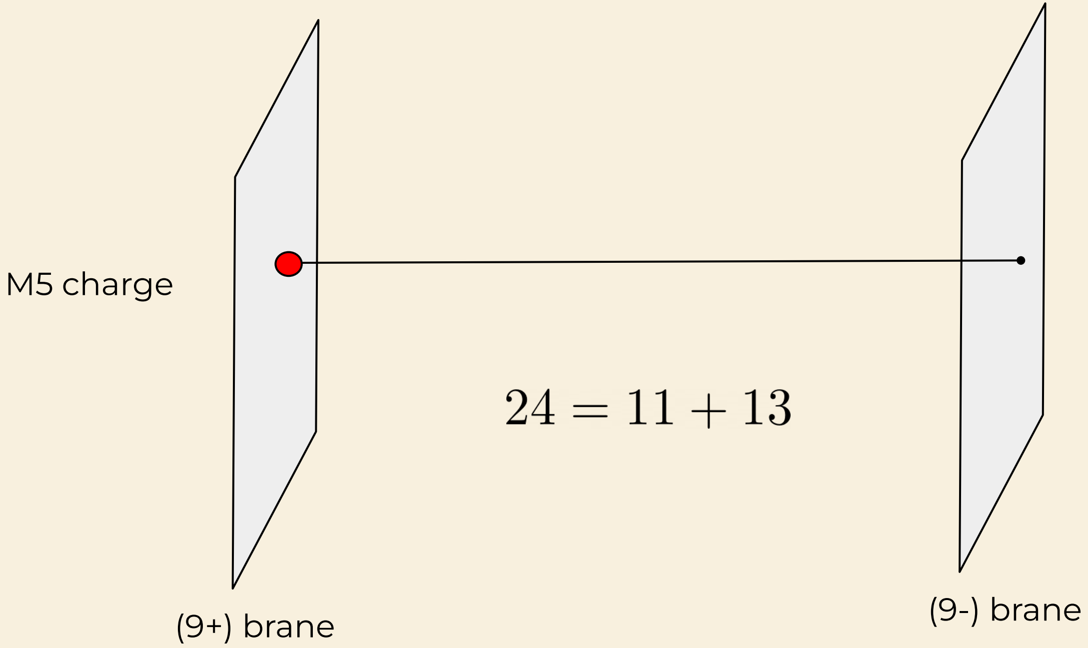

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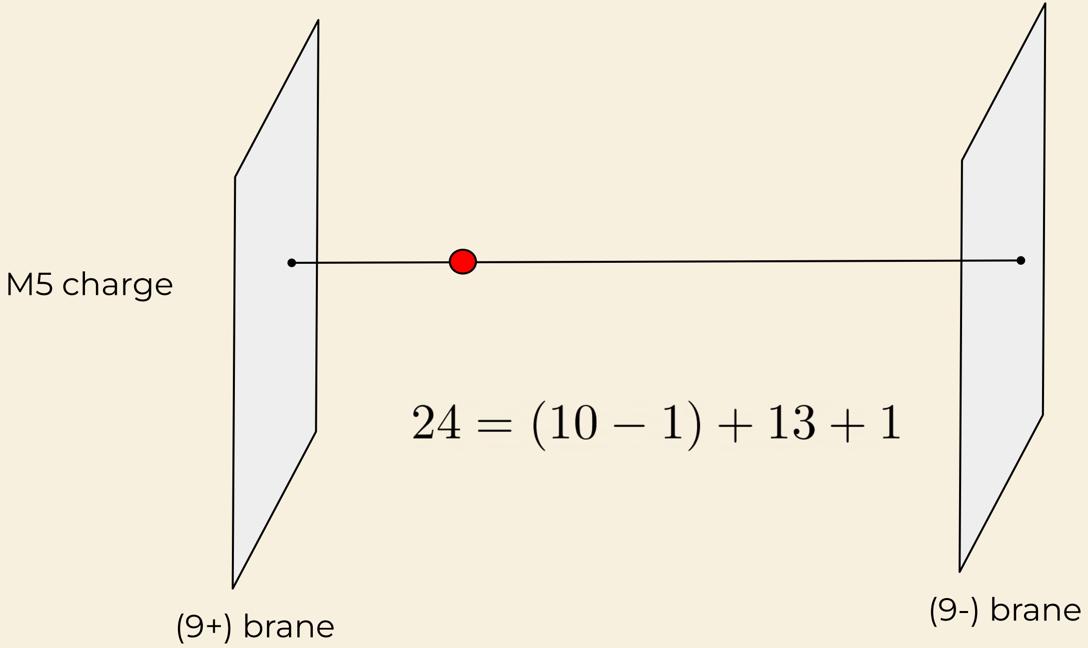

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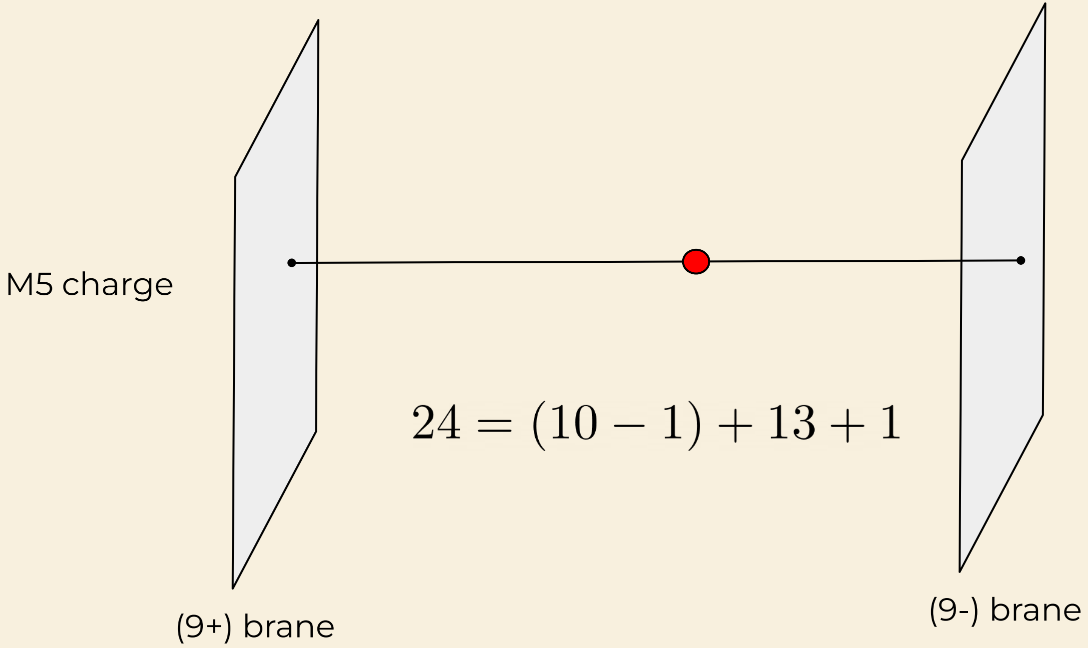

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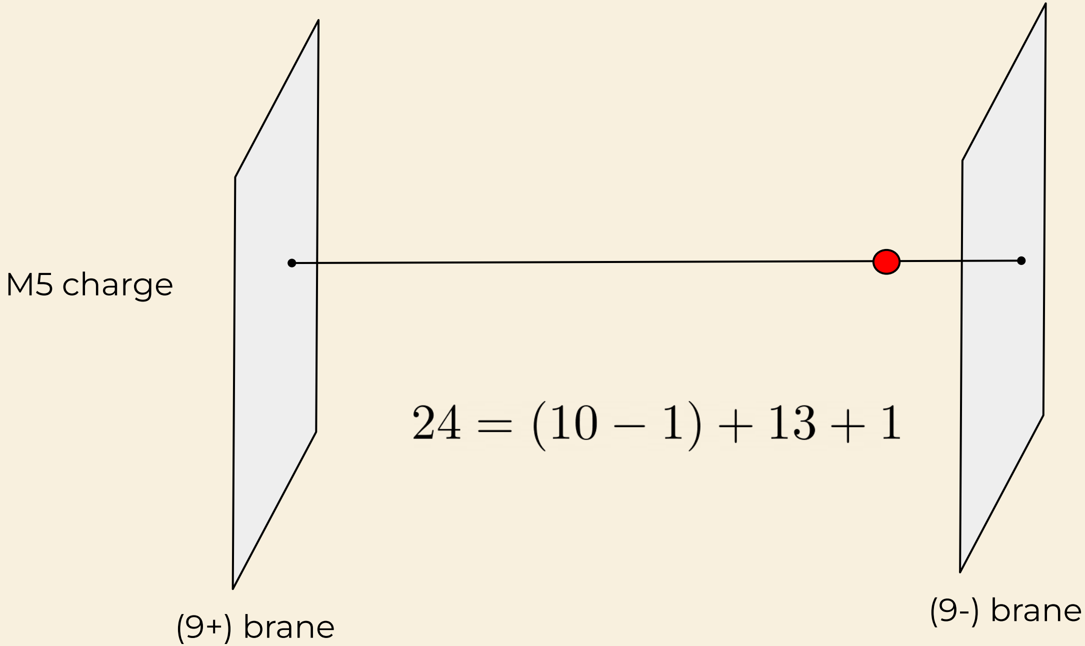

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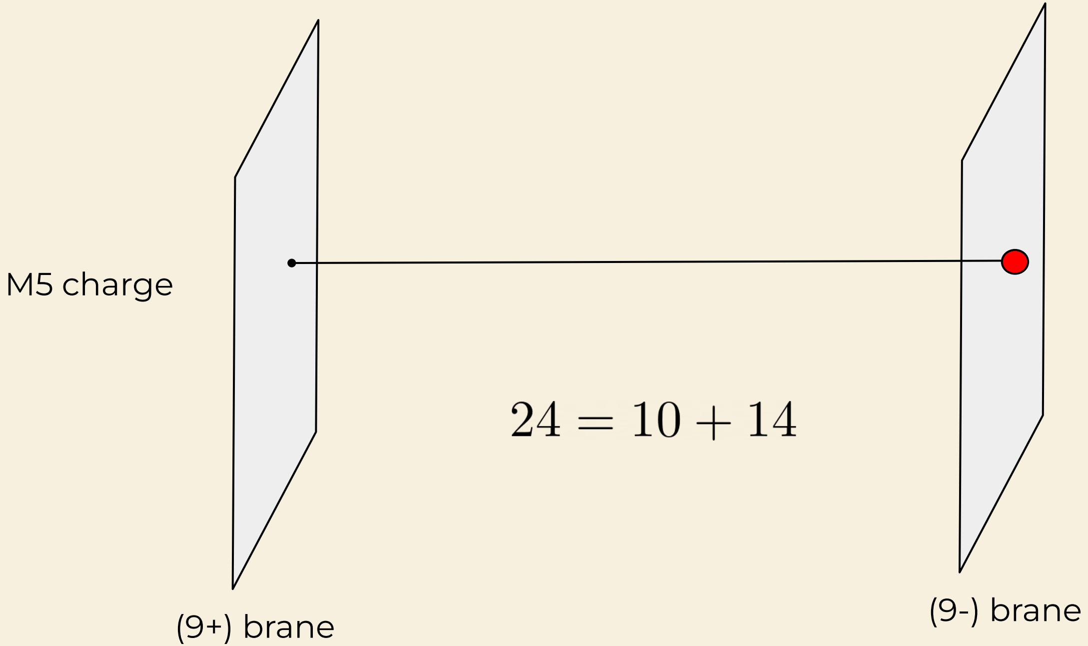

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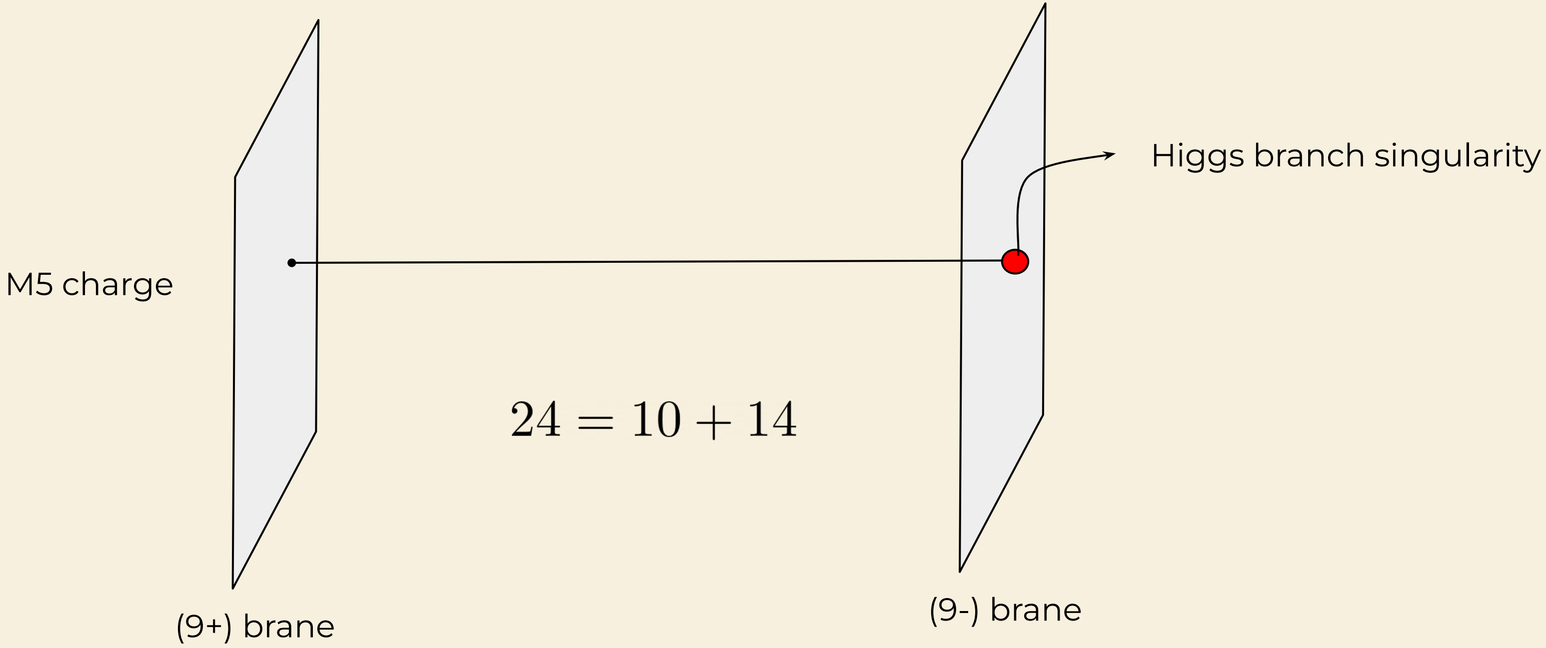

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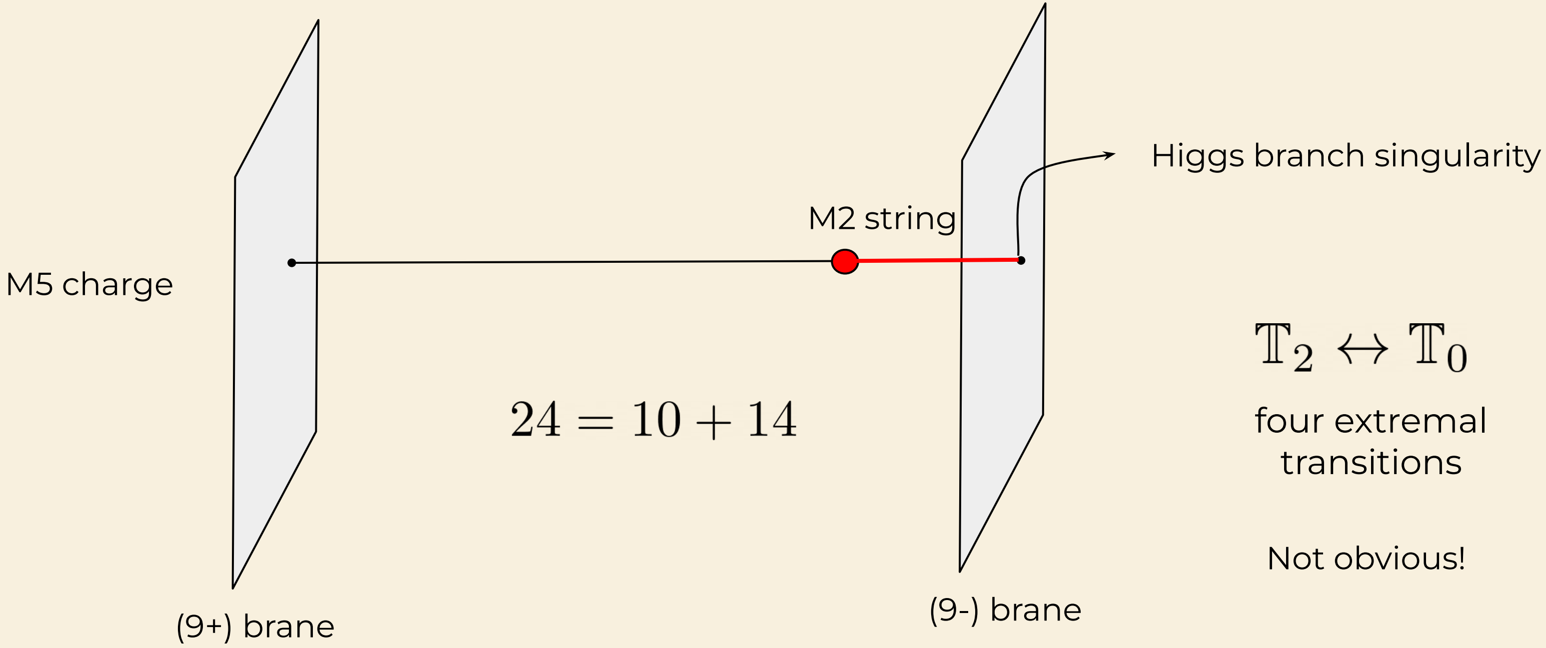
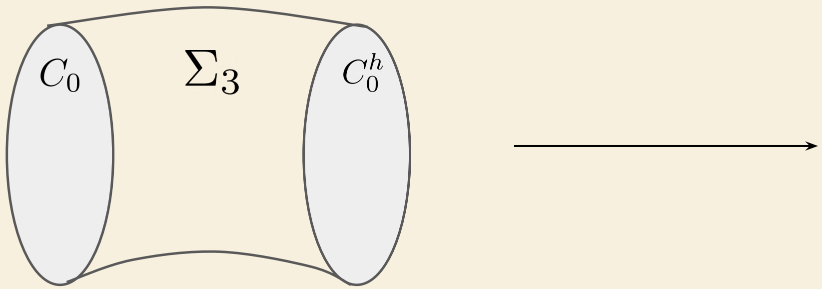


$$\mathbb{T}_2 \leftrightarrow \mathbb{T}_0$$

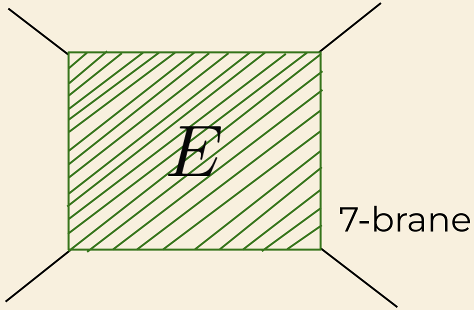
four extremal transitions

Not obvious!

The missing chiral comes from n.p state (like in conifold transitions)



Massive $(V) : (5,3)_{V,m\neq 0}$



Stückelberg massive U(1)

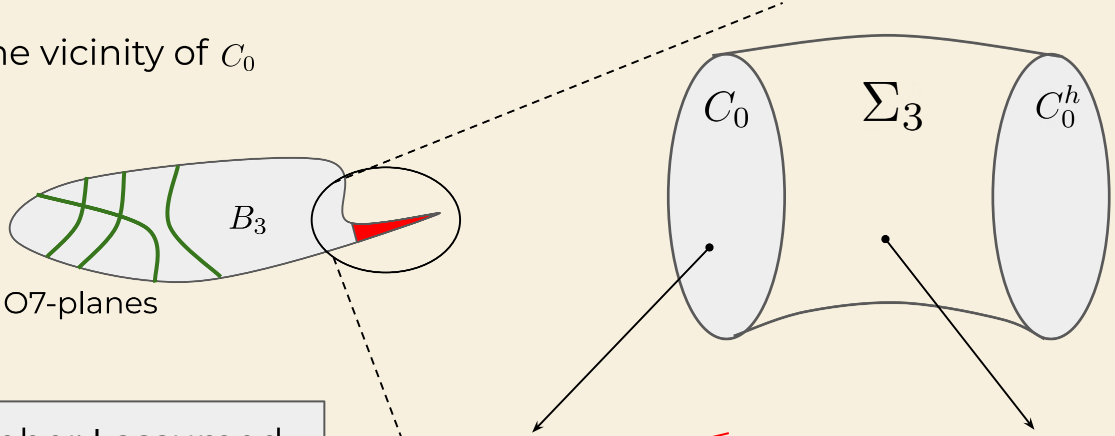
After the transition, a closed string U(1) is replaced by an open string U(1). In F-theory, closed and open string moduli are treated equally.

Same as in N=2. Different origin whether: Higgs or Coulomb branch.

Take the type IIB limit: $T^2 \hookrightarrow X_4 \to X_3$. After to orientifolding

$$t_0 = g_s^{-1/2} \int_{C_0} J_{X_3} \,, \quad b_2^{(0)} = \int_{C_0} B_2 \,, \quad c_2^{(0)} = \int_{C_0} C_2 \,, \quad c_4^{(0)} = \left(\int_{C_0} C_4 \right)^{\vee}$$

In the vicinity of C_0



Conifold setup

Higgs branch

$(H) : (4,0)_H$

$(C) : (2,0)_C$

Massive $(V) : (5,3)_{V,m\neq 0}$

Massive $(V) : (3,1)_{V,m\neq 0}$

Remember I assumed

$$\bar{K}_{B_3} \cdot C_0 = 0$$