ICN UNAM

AVOIDING IMAGINARY MASSES

STABILIZING THE CHIRAL PHASE IN THE LINEAR SIGMA MODEL BEYOND MEAN-FIELD

Second Latin American Workshop on Electromagnetics Effects in QCD
2025

Present by

Luis C. Parra L.

Colaborators

Finite (T)

Alejandro Ayala
Renato Zamora
Luis Hernandez
Bruno El-Bennich

Finite muB

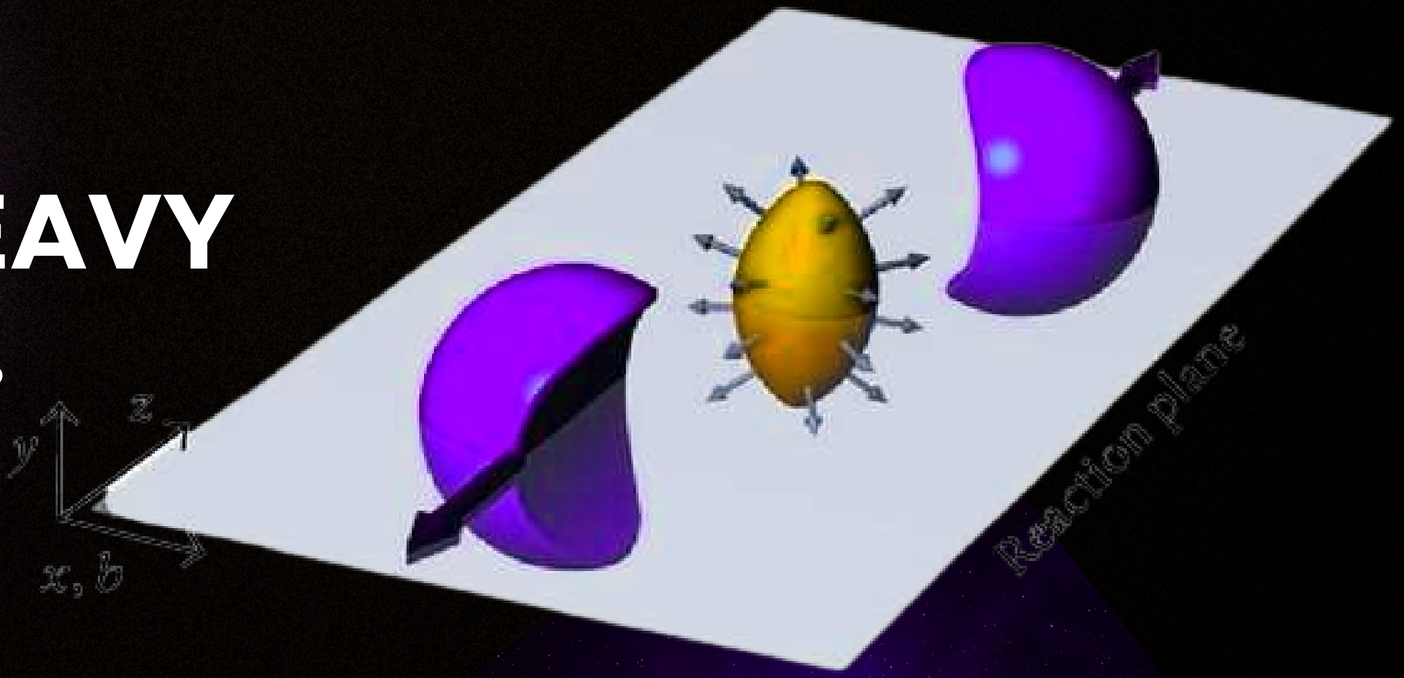
Alejandro Ayala
Ricardo Farias
Bruno Lopez

Wednesday, Nov. 26, 2025

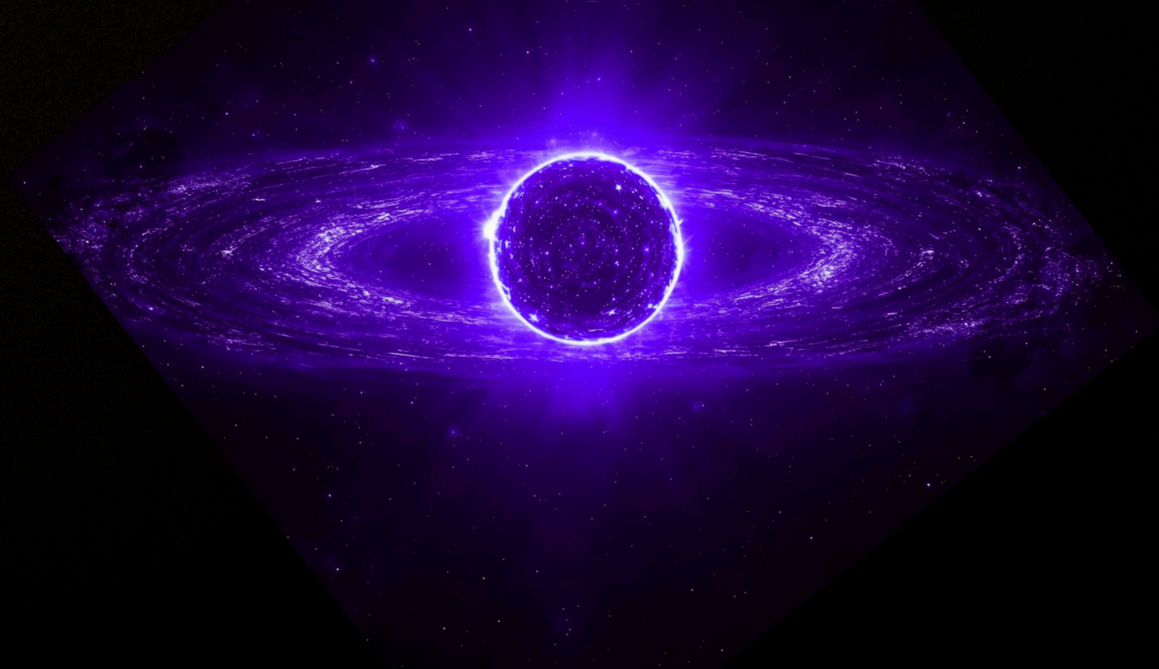
WHO GENERATES THE STRONGEST MAGENTIC FIELDS?

USUAL SUSPECTS

- **PERIFERICAL HEAVY ION COLISIONS.**



- **NEUTRON STARS.**



WHAT THEY HAVE IN COMMON?

NOT ONLY MAGENETIC FIELD

ALSO AND ρ_B

$T - B$ OR $\mu - B$

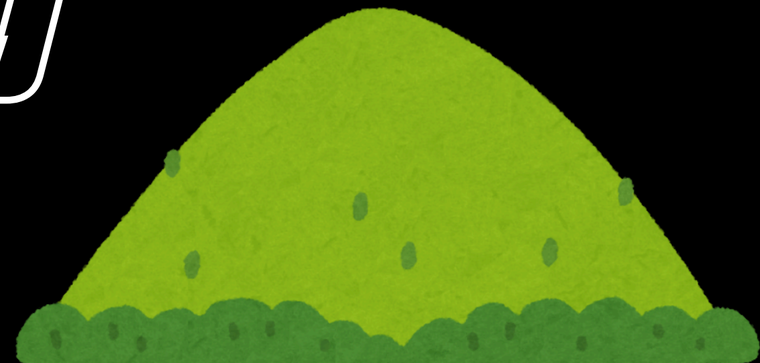
SOME OPTIONS

Effective models	Region
Holography	Strong couplings
Hadronic fields	Low Energy, nuclear physics
HLS	Vector mesons
Chiral models	Chiral restoration

CHIRAL MODELS AS LSMQ OR NJL

$$T - B \quad \text{OR} \quad \mu - B$$

IMAGINARY MASSES

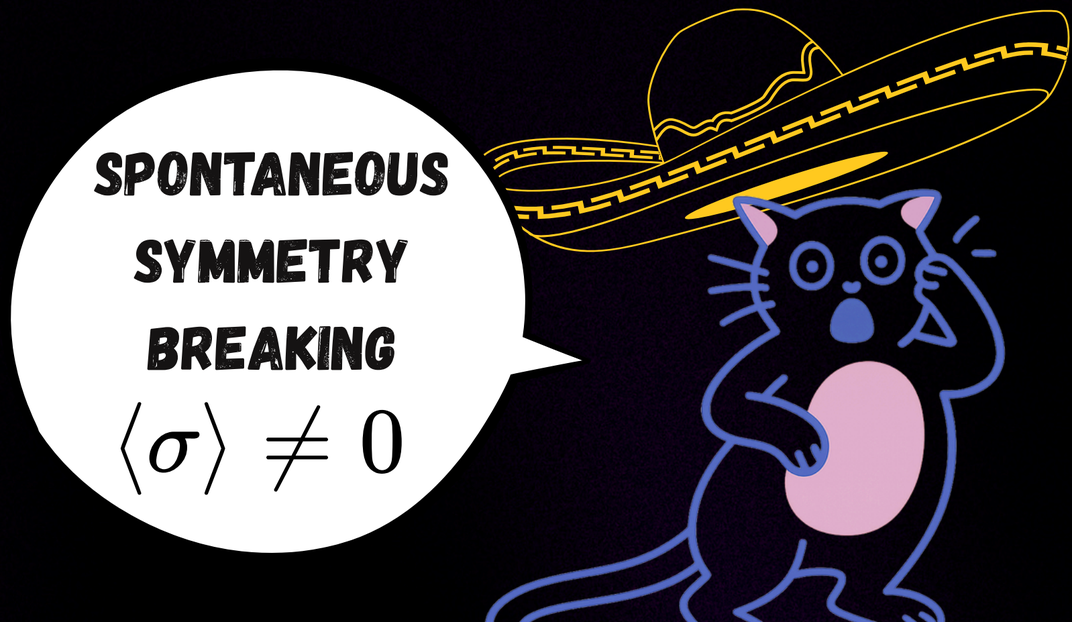


LET BE A SYMETRIC AND PERFECT WORLD.

$$\mathcal{L} = \frac{1}{2}\left[(\partial_\mu \sigma)^2 + (\partial_\mu \vec{\pi})^2\right] - \frac{\mu^2}{2}(\sigma^2 + \vec{\pi}) - \frac{\lambda}{4}(\sigma^2 + \vec{\pi}^2)^2$$
$$+ i\bar{\psi}\gamma^\mu \partial_\mu \psi - ig\bar{\psi}\gamma^5 \vec{\tau} \cdot \vec{\pi}\psi - g\bar{\psi}\psi\sigma$$

EVERYTHING IS IN THE GROUND STATE. TOO BORING!!

We take $\mu^2 \to -a^2$ with $a^2 > 0$, which gives us the famous -and stylistically questionable- ‘Mexican hat’ potential.



MESON MASSES

In LSMq

$$m_\pi^2 = \lambda v^2 - a^2$$

$$m_\sigma^2 = 3\lambda v^2 - a^2$$

$$v = \langle \sigma \rangle$$

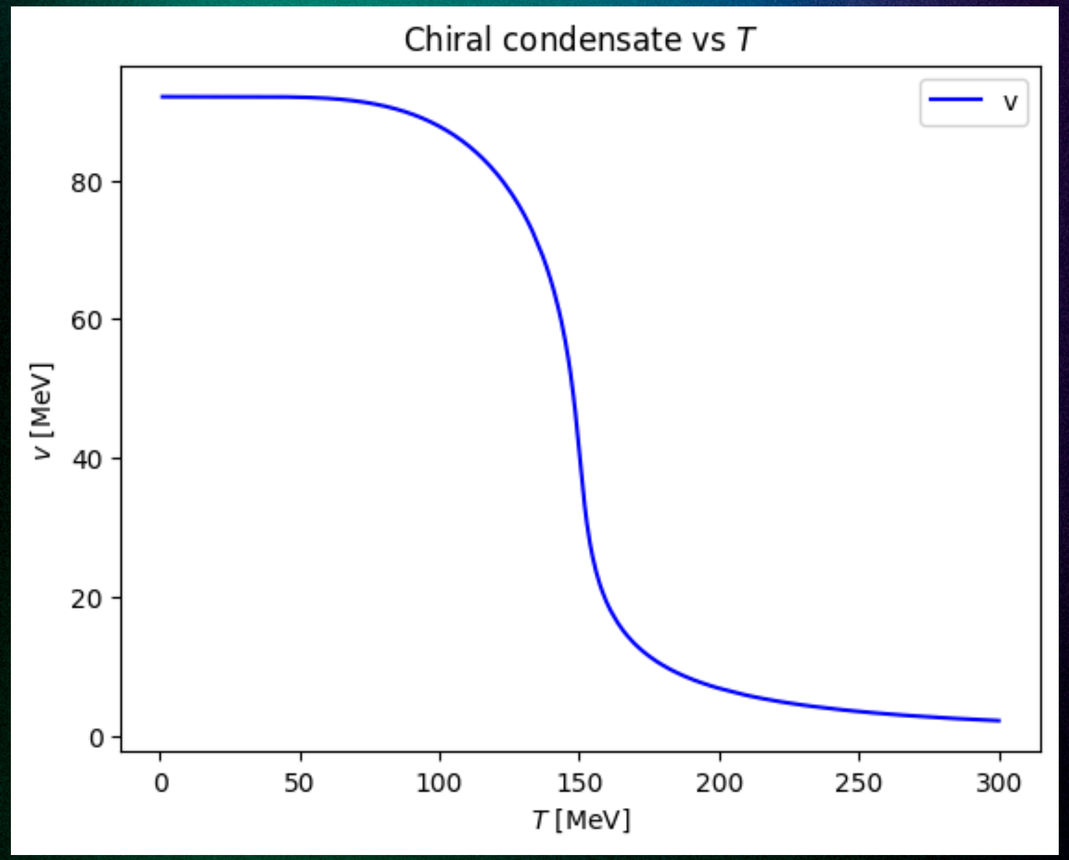
MESON MASSES

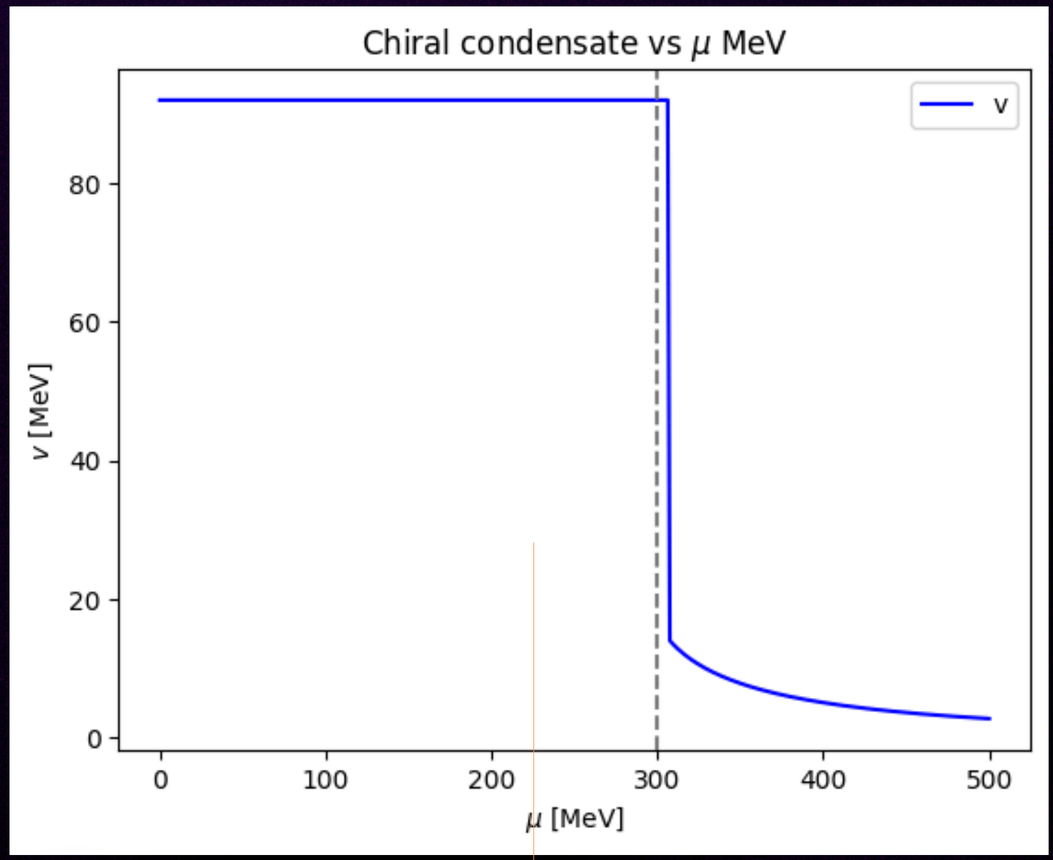
Explicit symmetry breaking term

$$\mathcal{L} \to \mathcal{L} + h(\sigma + v)$$

DRA. JOANA GAVE US A HINT YESTERDAY ACTUALLY

IF YOU DON´T IMPLEMENT ANYTHING

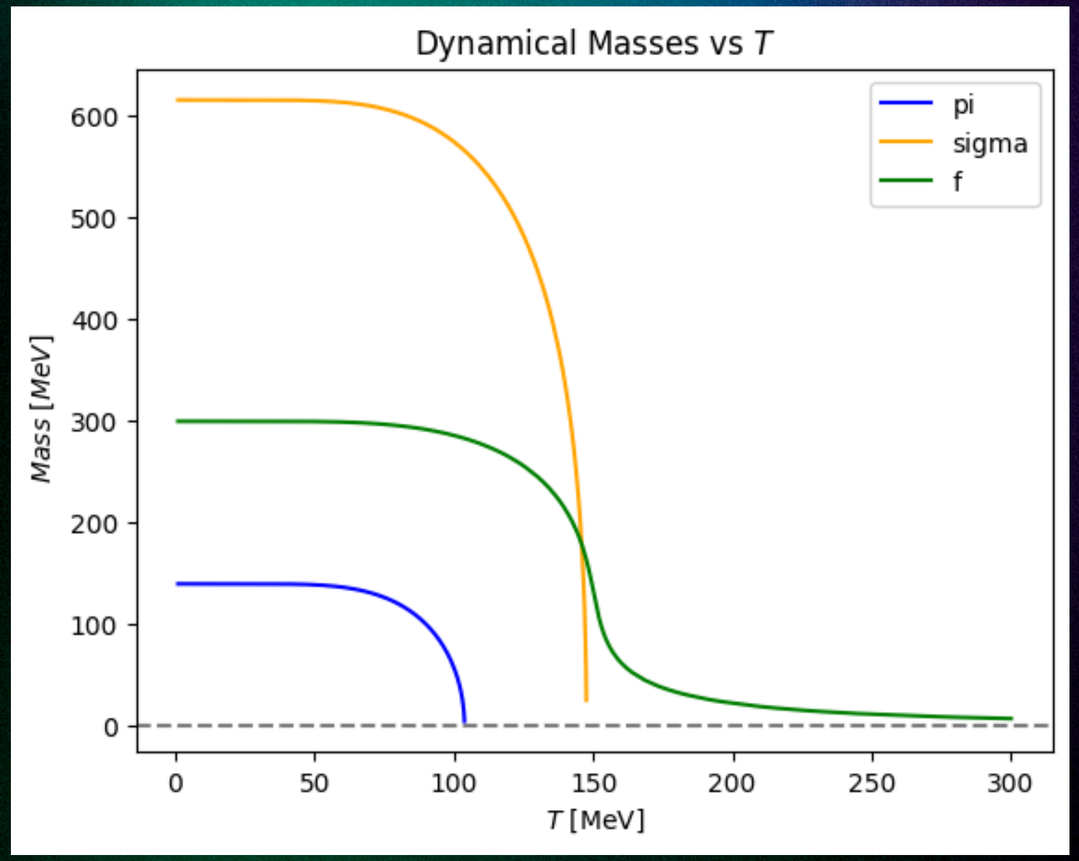


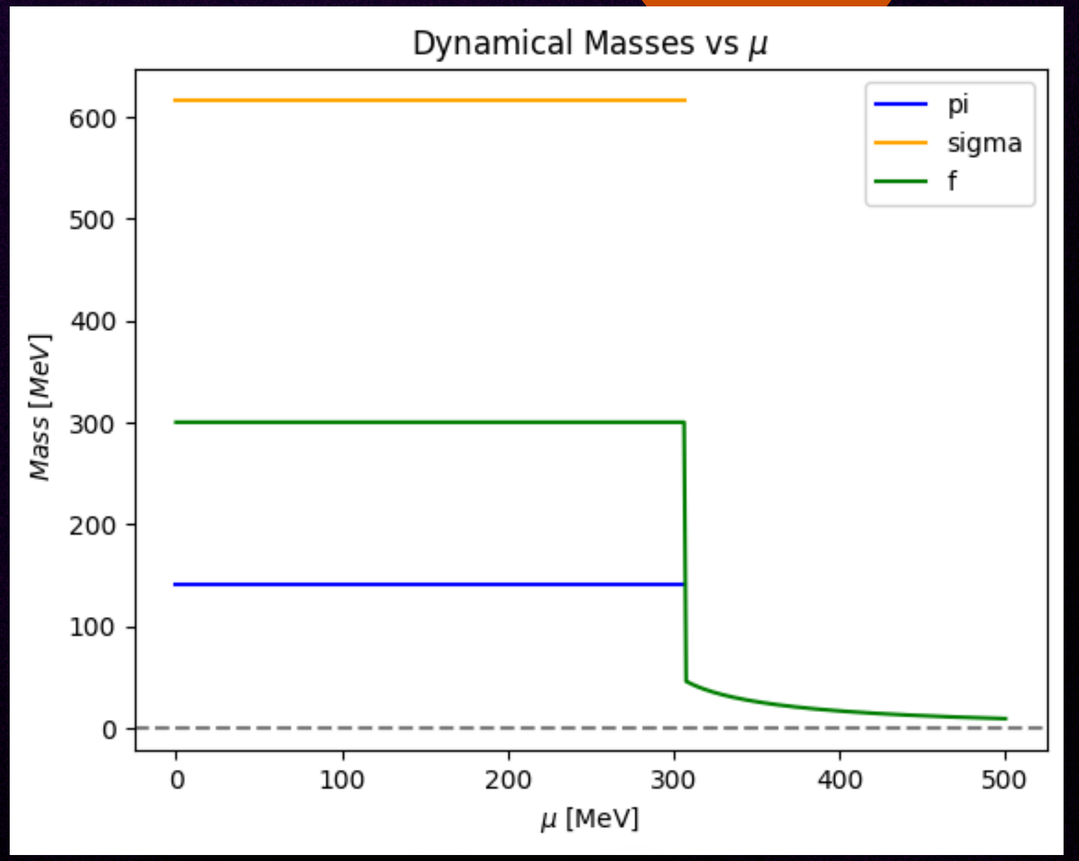


yeah!!

IF YOU DON'T IMPLEMENT ANYTHING

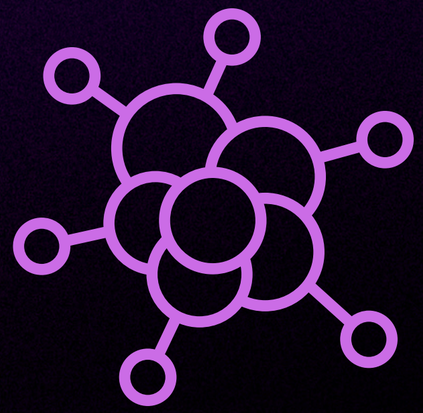
$$m_\pi^2 = \lambda v^2 - a^2$$
$$m_\sigma^2 = 3\lambda v^2 - a^2$$

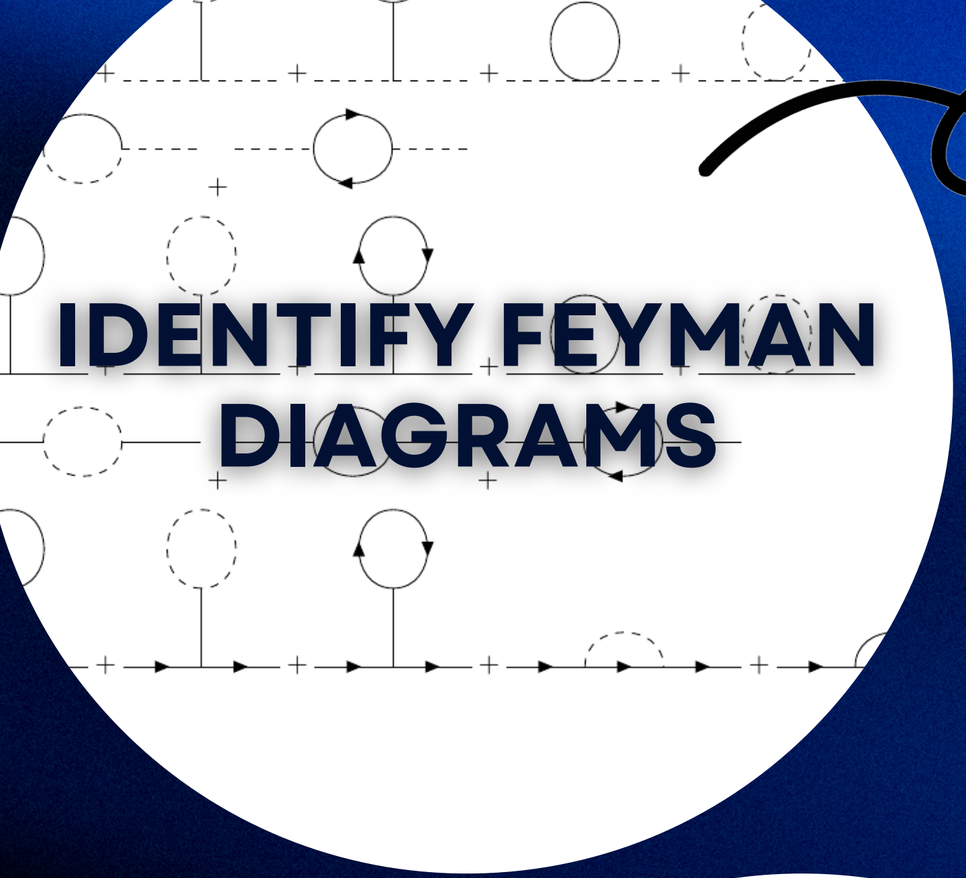




Tachyonic mesons? oh no!!

1. SELFENERGY
2. BETHE-SALPETER EQUATIONS
3. NON LINEAR EFT
4. LIPPMANN–SCHWINGER EQUATIONS





IDENTIFY FEYMAN DIAGRAMS

térmica a las autoenergías

alculamos los resultados de las integrales e identificam s l
la resumación sobre todos los diagramas de anillo, con

INCLUDE MEDIUM:
MATSUBARA FREC.
COVARIANT DERIV.
LANDAU LEVELS - RITUS EQ.

```
dataMpi, a - b x^2, {a, b}, x];
lm["BestFitParameters"];
ModelFit[tmpdataMs, a - b x^2, {a, b}, x];
odelo no lineal
= a /. nlm["BestFitParameters"];
LinearModelFit[tmp
ta a modelo no lineal
[i] = a /. nlm["BestFitParameters"];
ot[{Transpose[{MuB, Finalv}], {{300, 0}, {300, 94}}}, PlotRange → {Aut
a d··· transposición
rango de repr··· au
```

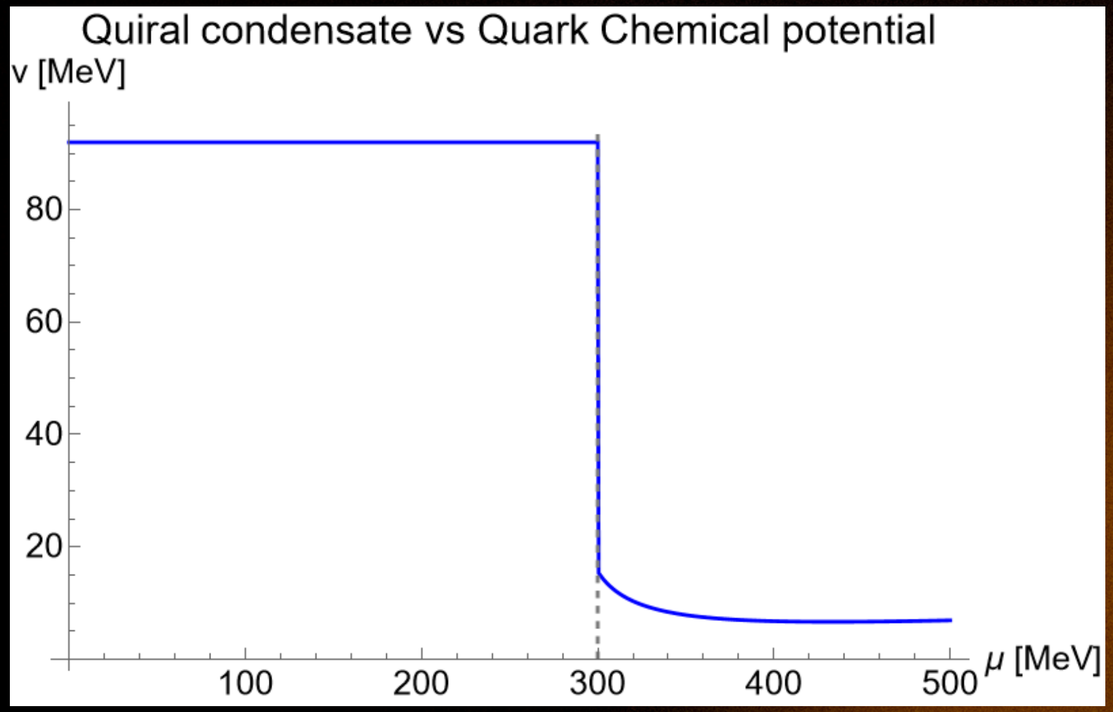
VISUALIZE

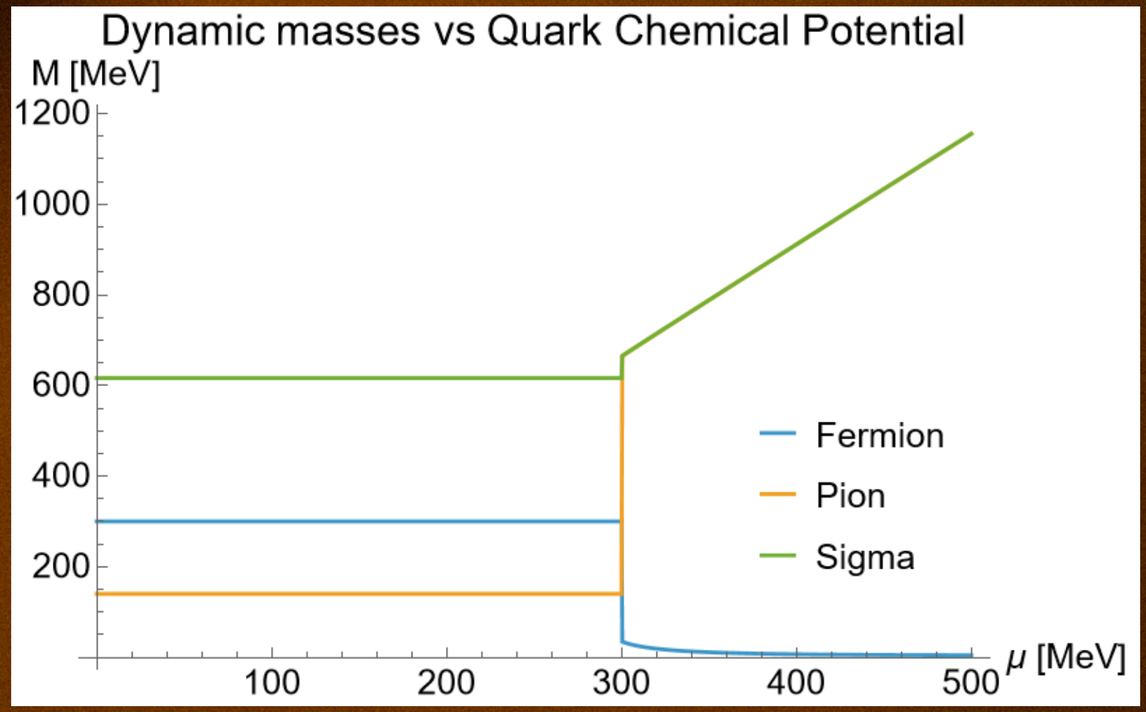
```
_f, v, mu,T):
( 4 * np.pi**2 )
- np.sqrt(q**2 + M_f**2 + mu) / (
, M_p, M_s, M_f, v, mu,T):
2 ) / ( 4 * np.pi**2 )
* ( 3 * M_f - np.sqrt(q**2 + M_f**2) + mu) / (
f*t
mFermion(M_p, M_s, M_f, v, mu,T):
quad(SE_fTp, 0, infty, args=(M_p, M_s, M_f, v, mu
M_p:
```

PROGRAM

WITH SELFENERGY

$$M_\pi^2 = \lambda v^2 - a^2 + \Pi_\pi$$
$$M_\sigma^2 = 3\lambda v^2 - a^2 + \Pi_\sigma$$





Tachyonic mesons? oh no!!

WHY IT WORKS?

COUNTER EXAMPLE:

Pion Condensate

$$m_\sigma^2 = \lambda(3v^2 + \Delta^2) - a^2,$$
$$m_\pi^2 = \lambda(v^2 + \Delta^2) - a^2,$$
$$m_{ch}^2 = \lambda(v^2 + 2\Delta^2) - a^2.$$

Isospin chemical potential

COMPARISON

Selfenergy

Pion cond.

Schwinger
proper-time

CONCLUSION

- WE HAVE EXPLORED DIVERSE METHODS TO AVOID THE APPEARANCE OF IMAGINARY MASSES.
- A FUNDAMENTAL OBSERVATION UNIFIES ALL THESE APPROACHES: IT IS CRUCIAL TO ENDOW THE PARTICLES WITH INFORMATION ABOUT THE MEDIUM IN WHICH THEY PROPAGATE.

The tachyon is a ghost in our theoretical machinery, telling us we are expanding around the wrong vacuum. Our job is to listen to it and evolve the vacuum along with the medium.

Thank all