Quantum Field Theory in a nutshell

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WHY is QFT necessary?

Concept of **Locality** and existence of **Quantum fields**.

✓ **Fields** (E field) are fundamental in nature.

✓ Upon quantization of ripples, allows for the **creation** of particles (photons).

WHAT is QFT?

Same formalism used in QM also applied to QFT

- Classical DOF are **fields**.
- Promote DOF to **operator** valued functions in Hilbert Space.

Scalar Field Theory

- **Klein Gordon** equation describes the dynamics of the scalar field:

$$\partial_\mu \phi \partial^\mu \phi + m^2 \phi = 0$$

- Quantization takes place via canonical **commutation** relations

$$[\phi(x,t), \pi(y,t)] = i\delta(x-y)$$

- **Creation** and **annihilation** operators, particles created have **n-integer spin** and obey **Bose-Einstein** Stats, called **Bosons**!
- **Spectrum** of the system can be found.

Dirac Field Theory

- **Dirac** equation describes the dynamics of the field:

$$(i\gamma^\mu \partial_\mu - m)\psi = 0$$

- Main physics lies in **gamma** matrices:

$$\{\gamma^\mu, \gamma^\nu\} = \gamma^\mu\gamma^\nu + \gamma^\nu\gamma^\mu = 2\eta^{\mu\nu}1$$

- From quantization, particles created have **half-integer spin** and obey **Fermi-Dirac** Stats, called **Fermions**!

Conclusion

Free fields, we establish:

- Existence of **indistinguishable** particles
- Combination of **SR +QM** (Particle number never conserved)
- Existence of **antiparticles** (as seen with Dirac FT)

Both Klein Gordon and Dirac equations are **Lorentz invariant**.

Particles created are subject to **Spin statistics theorem** in QFT

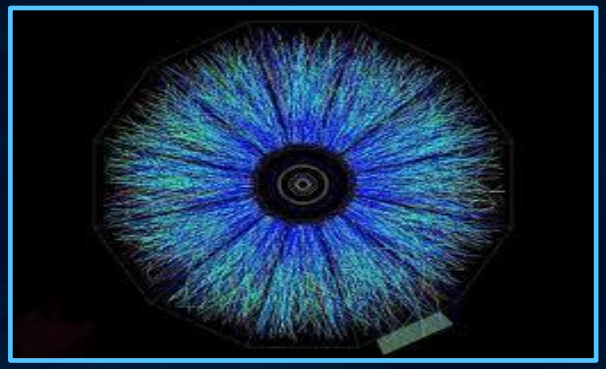

Fig 1: RHIC accelerator: example of SR+QM [1]

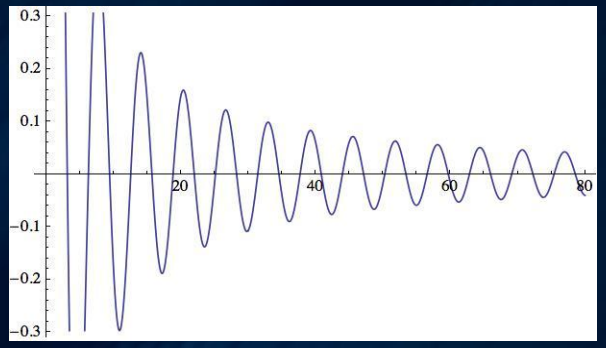

Fig 2: Application of QFT: investigating the dynamics of the Inflaton field [2]

References: [1] Tong D., **(2007)** *Quantum Field theory*, University of Cambridge Part III Mathematical Tripos.

[2] Kofman L., Linde A.D. and Starobinsky A.A., **(1997)** Toward the Theory of *Reheating after Inflation*, arXiv:hepth/9704452v2.

Acknowledgment: Dr. Mazumdar has been a great mentor and I have definitely learnt a lot for this experience.