SECTION GOALS:
- REVIEW EACH WEEK'S LECTURES
- ADDRESS ISSUES w/ ~~HOMEWORK~~ HW
- "BIG PICTURE" & INTERESTING COMMENTS

→ GET USED TO TALKING TO EACH OTHER IN THE LANGUAGE of QFT! (very IMPORTANT FOR THOSE of YOU GOING INTO RESEARCH)

THE SINGLE MOST IMPORTANT THING TO GET FROM TODAY'S SECTION:

Physics is a social activity

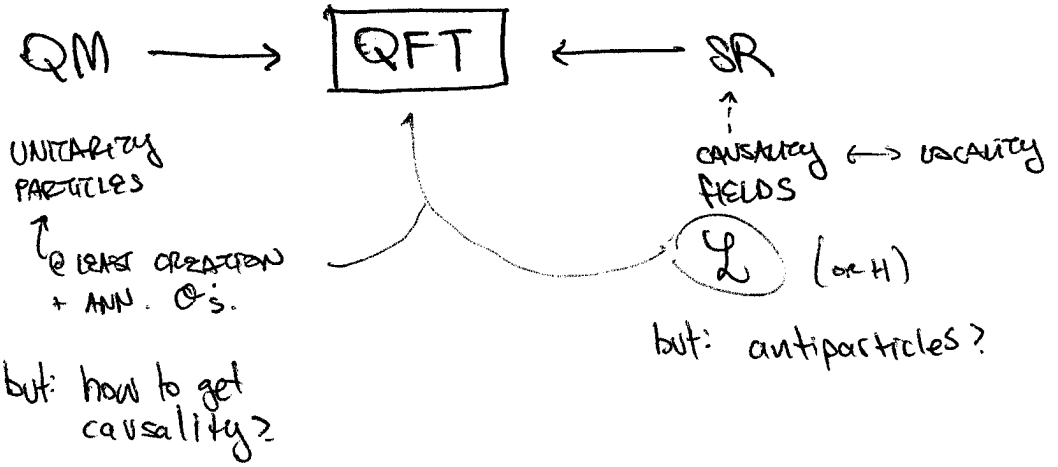
YOU SHOULD COLLABORATE ON HW (esp for advanced classes)
- YOU'LL LEARN FROM THE PROCESS of DISCUSSING PHYSICS
- PREPARATION FOR RESEARCH
- also... makes grading easier!

TOP QUIZ: IS QFT A THEORY of PARTICLES OR FIELDS?

→ SOMEWHAT PHILOSOPHICAL, BUT THE POINT IS THAT ALL of THE FUNDAMENTAL PARTICLES WE OBSERVE ... ARE PARTICLES.

(LOADED WORD!)

[LHC ISN'T OBSERVING WAVES - YOU SEE STRAIGHT LINE TRACKS (CURVED IN B FIELD)]



SO FROM QUANTUM : $|\vec{p}, \ldots\rangle \sim a^\dagger_{\vec{p}}\,|0\rangle$

- $|\vec{p}, \ldots\rangle$: 1-PARTICLE STATE; $\vec{p}$: ADDITIONAL LABELS (ignore)
- $a^\dagger_{\vec{p}}\,|0\rangle$: VACUUM (also a funny thing in QFT)

NORMALIZATION WAS DISCUSSED @ LENGTH IN CLASS

$$\sqrt{2E_{\vec{p}}}\, a^\dagger_{\vec{p}}\,|0\rangle$$

a word on normalization : ALL RELATIVITY eg OUR INTEGRALS

$$\int d^3\vec{p}\,\left(\frac{1}{2E_{\vec{p}}}\right) \leftarrow \delta(p^2 - m^2)\, d^4p$$

- $\int d^3\vec{p}$: bar: FOURIER
- $\delta(p^2 - m^2)\, d^4p$: $d^3p\ \frac{dE^2}{2E}$

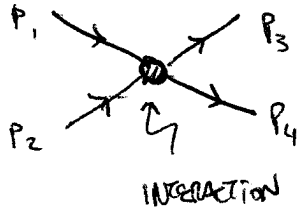
... but don't let this obfuscate the physics!

WE CAN WRITE DOWN A HAMILTONIAN

$$H = \sum_{\vec{p}} E_{\vec{p}}\, a^\dagger_{\vec{p}}\, a_{\vec{p}} + \text{INTERACTIONS}$$

$\sum_{\vec{p}}$: READY AN INTEGRAL

IN FACT, CAN IMAGINE HOW WE GET TO FEYNMAN DIAGRAMS



$$\sim \langle \vec{p}_3, \vec{p}_4 | \left(\prod_{i=1}^{4} d^3p_i\right) a^\dagger_4 a^\dagger_3 a_2 a_1 \, | \vec{p}_1, \vec{p}_2 \rangle$$

- $a^\dagger_4 a^\dagger_3 a_2 a_1$: × some function $V(p_1, \ldots)$
- × MOMENTUM CONS $\delta^{(4)}(p + \ldots)$

SO FAR, JUST QUANTUM MECHANICS.

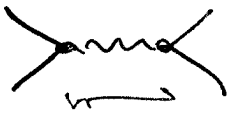
BUT: HOW DO I MAKE THIS CAUSAL ?

↕

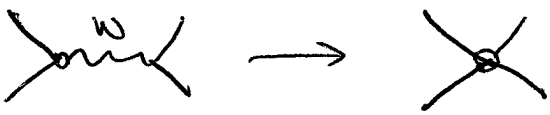
LOCAL ← POINT INTERACTIONS CAN'T BE BOOSTED INTO NONCAUSAL SPACELIKE SEPARATIONS

BUT: "POINTLIKE" IS AGAIN A FUNNY IDEA.

eg. WE KNOW THAT PHOTONS MEDIATE QED



nonlocal ← indeed, QED is long ranged



FERMI THEORY

BOTH ARE VALID QFTs DESCRIBING SAME PHYSICS (BUT @ DIFFERENT SCALES)

TO MAKE THINGS LOCAL, PACKAGE OPERATORS INTO FIELDS THAT DEPEND ON SPACETIME, NOT MOMENTUM

⇒ FOURIER TRANSFORM

$$\phi_+(x) \sim \int \frac{d^3p}{2E_p} a_p^\dagger e^{i\vec{p}\cdot\vec{x}}$$

$$\phi_-(x) \sim \int \frac{d^3p}{2E_p} a_p e^{-i\vec{p}\cdot\vec{x}}$$

h.c. (ANTIPARTICLES) ↑ more on this later.

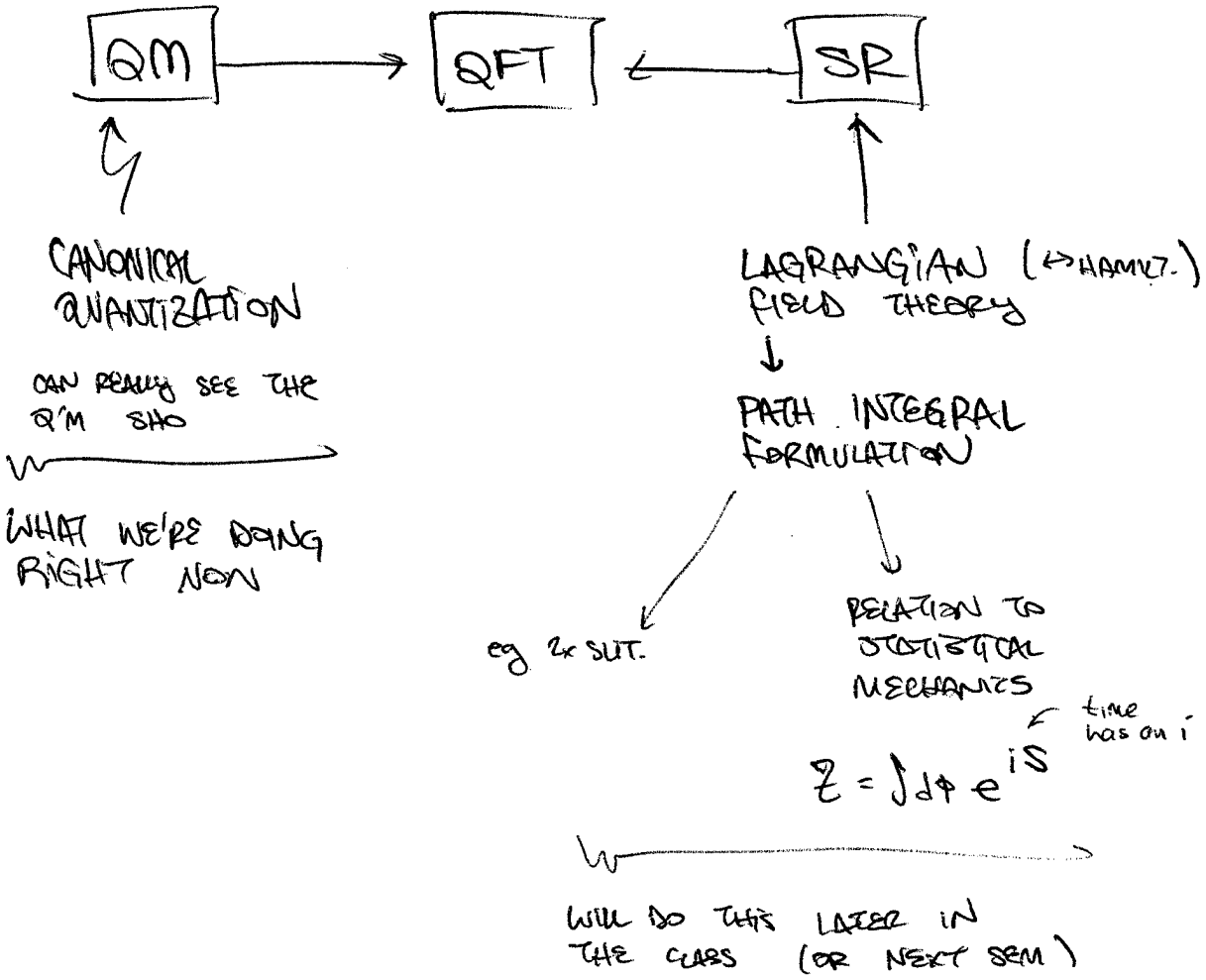
THEN WRITE THE INTERACTIONS LOCALLY:

$$H_{int} \sim \phi_+(x)\phi_+(x)\phi_-(x)\phi_-(x)$$

SO: UNITARITY + LOCALITY = QFT

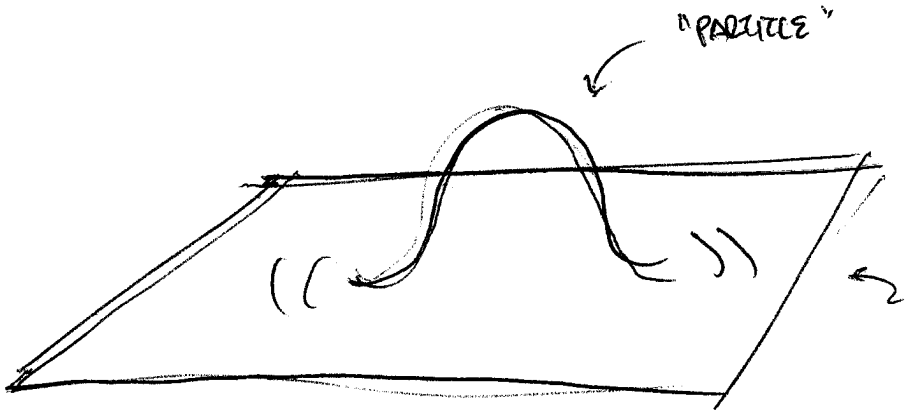
↑ QM ↑ SR

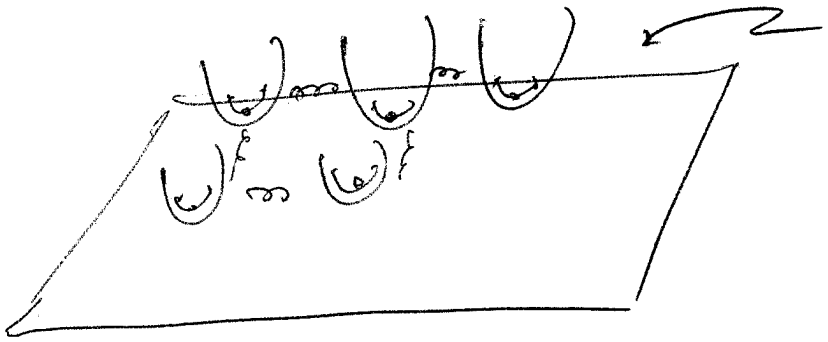
THERE IS ANOTHER SENSE IN WHICH WE CAN SEE THESE TWO THREADS:

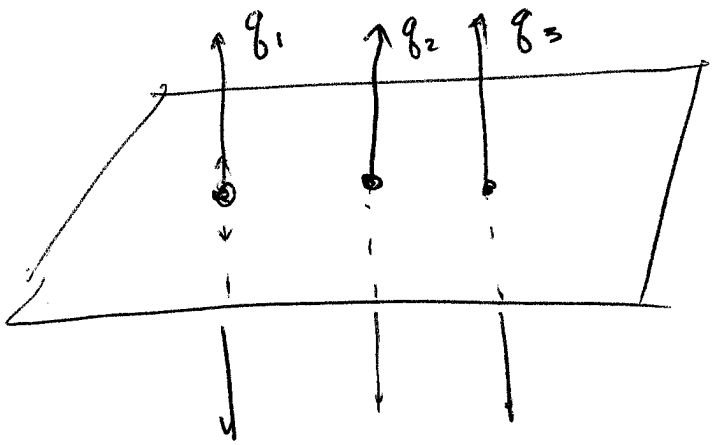


COMPLEMENTARY VIEWPOINTS.

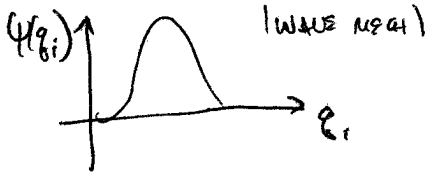
PICTURES







DO QM ON q_i



BUT EACH q_i IS COUPLED TO ITS NEIGHBOR q_{i+1}

... } INFINITELY MANY ;

LABEL AS FIELD:

$q \to \varphi$

$q_i \to \varphi(\vec{x})$

$H \sim (\partial\varphi)^2$

TELLS US ABOUT HOW NEIGHBORING OSCILLATORS ARE CONNECTED

~~INTRO~~

NEXT HOMEWORK: THE 2-POINT CORRELATION FUNCTION

↳ GIVEN AN Q'M EXCITATION HERE, WHAT IS PROBABILITY of SEEING A Q'M EXCITATION THERE?

$$\langle \phi(0)\, \phi(\vec{x}) \rangle$$

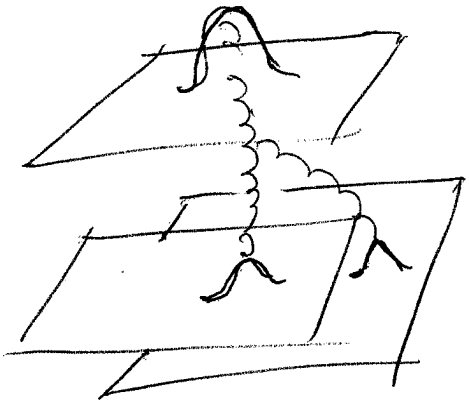
↑ TELLS US ABOUT HOW PARTICLES MOVE.

WE'LL BE ABLE TO DRAW DIAGRAMS: 

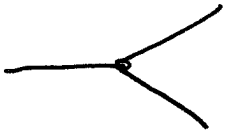
PREVIEW of BIG PICTURE

PUS "INTERACTIONS" BTWN NEIGHBORING OSCILLATORS JUST DESCRIBE PROPAGATION

INTERACTIONS of PARTICLES



WIGGLING FIELD INDUCES WIGGLES IN OTHER FIELDS



apology: FROM HEP PERSPECTIVE

↳ tools are identical for cond-mat th!

QFT BIG PICTURE

- INTERACTIONS of PARTICLES (RELATIVISTIC) ⟶ DRAW & COMPUTE FEYNMAN DIAGRAMS
- MODELS of QM+SR PHYSICS ⟶ WRITE $\mathcal{L}$'s, UNDERSTAND IMPLICATIONS, CONSISTENCY
- "DEEP" FEATURES of NATURE ⟶ eg AdS/CFT RENORMALIZ. GRP