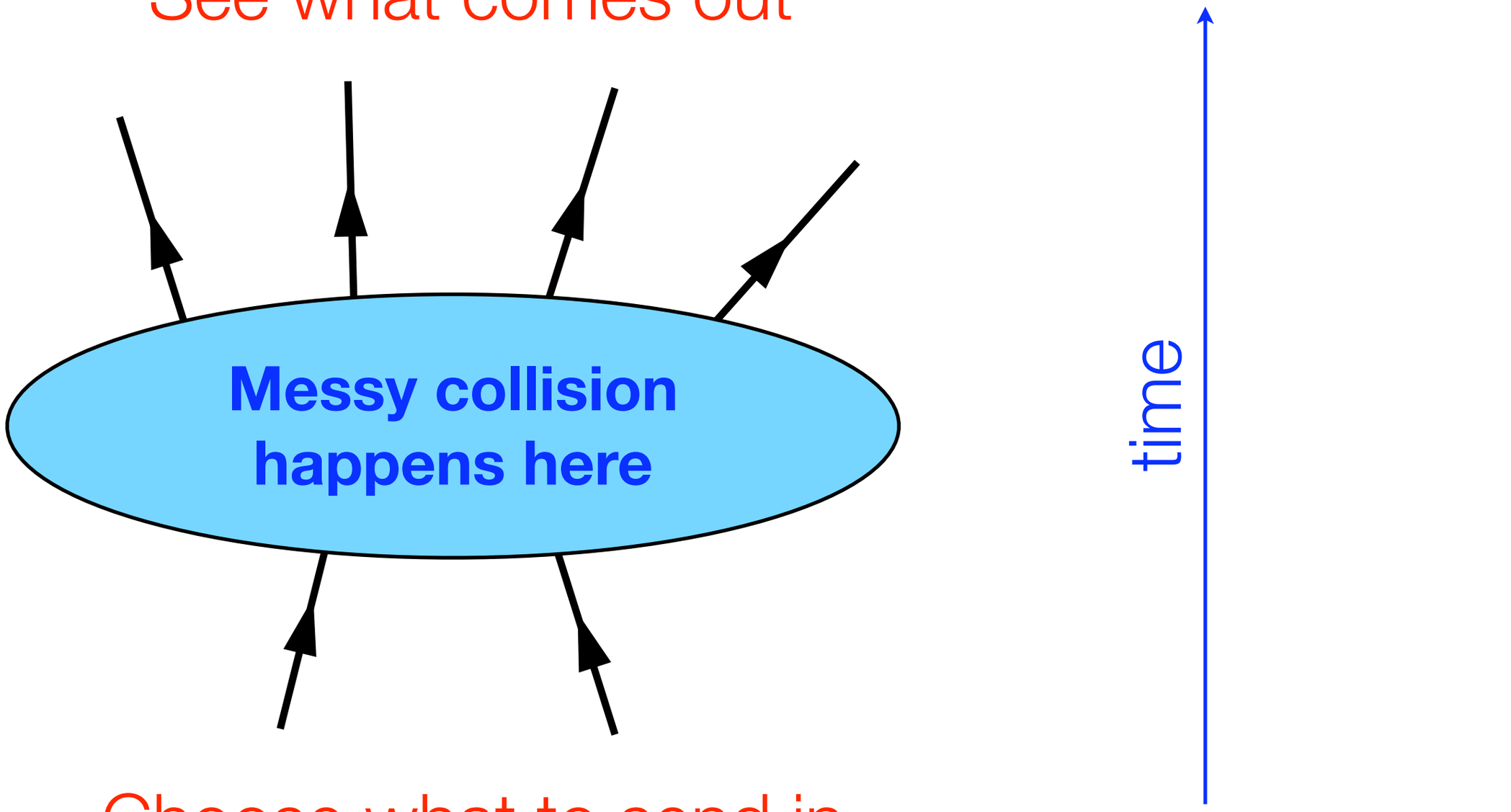
THE *Secret Life* OF SCATTERING AMPLITUDES

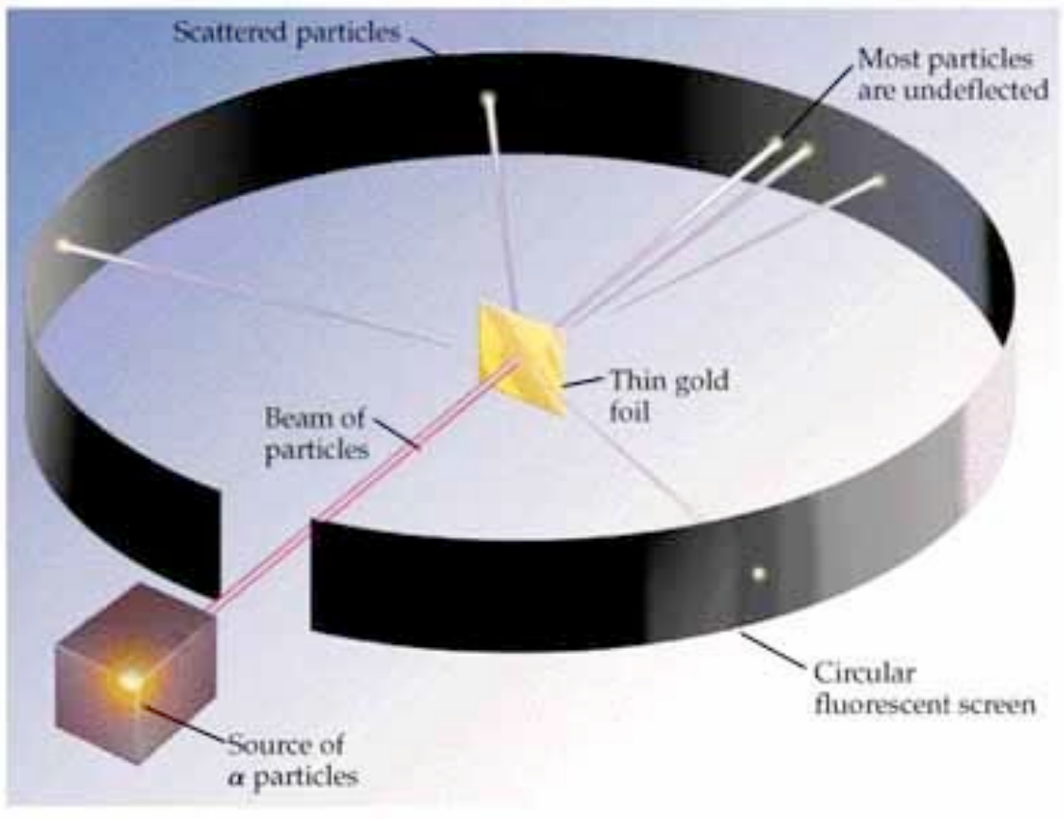
David Skinner - DAMTP

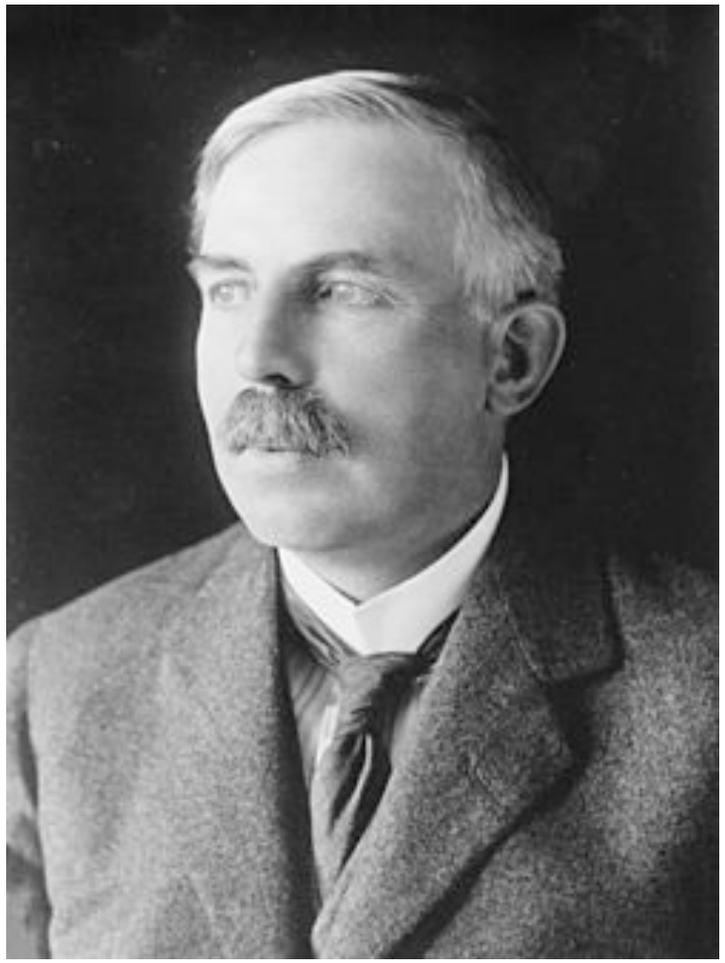
Fellows' Research Talks - 12/11/14

A scattering process is a description of what happens when stuff bumps into other stuff

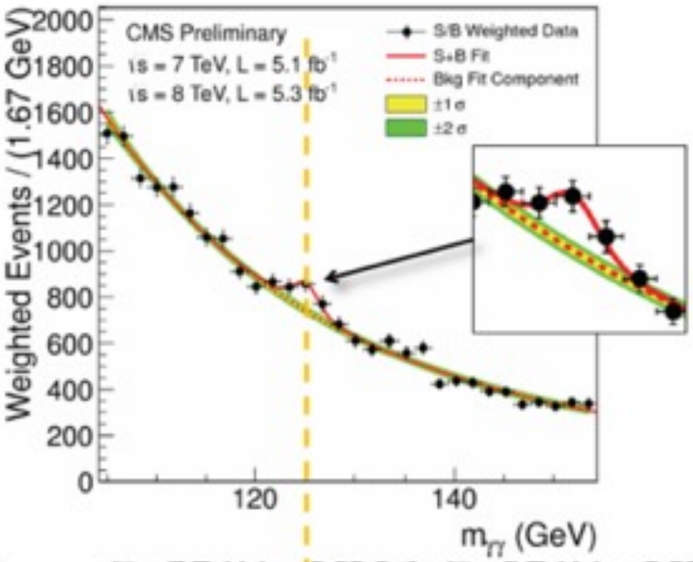


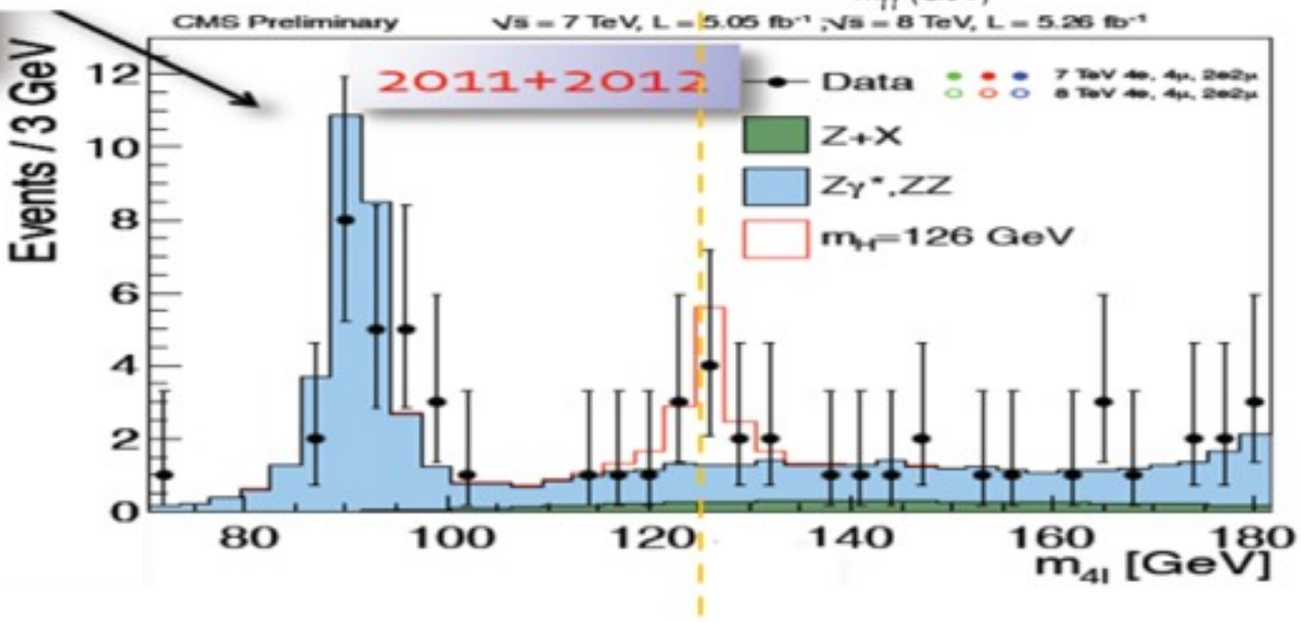
Rutherford discovered the atomic nucleus by scattering α-particles off thin gold foil



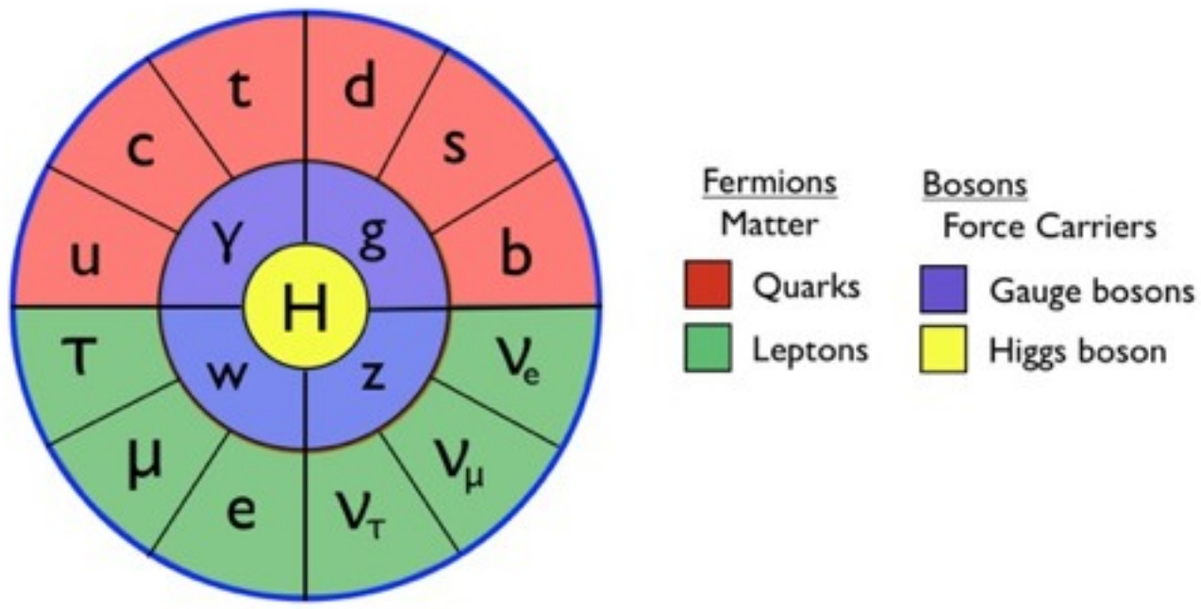


"It was quite the most incredible event that has ever happened in my life. It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you."

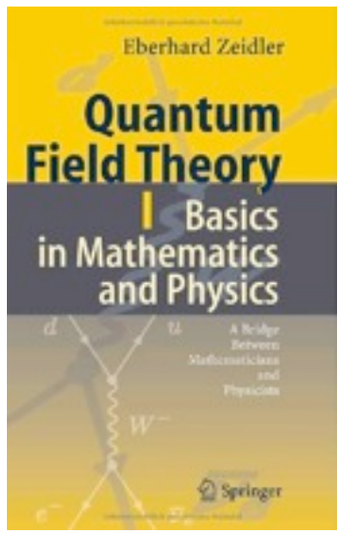


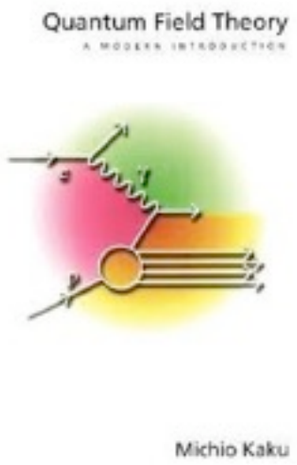


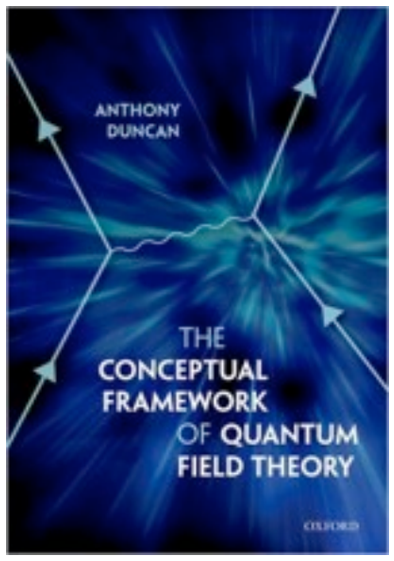
Most of what we know about the Standard Model - our best theory of particle physics - has been gleaned from scattering experiments

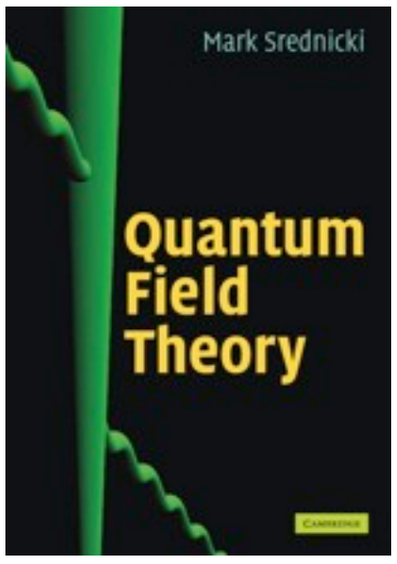


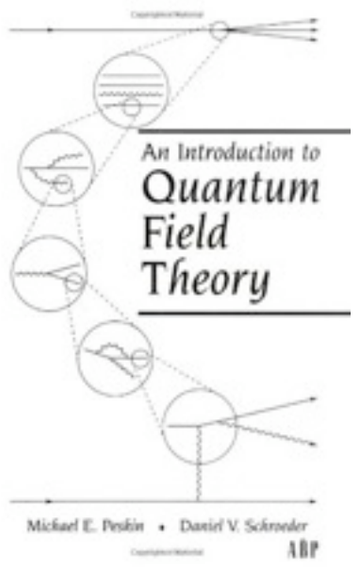
Particles of the Standard Model

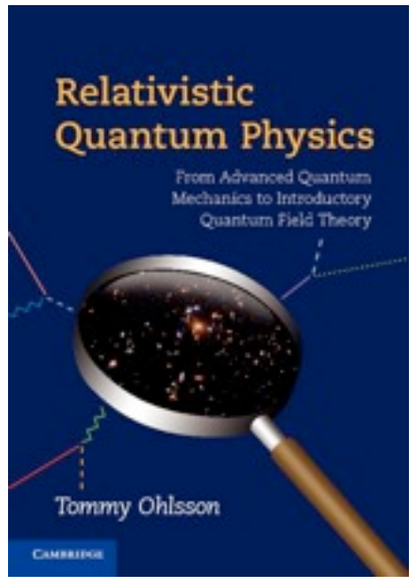

Eberhard Zeidler
Quantum Field Theory
I Basics in Mathematics and Physics
A Bridge Between Mathematicians and Physicists
Springer


Quantum Field Theory
A MODERN INTRODUCTION
Michio Kaku

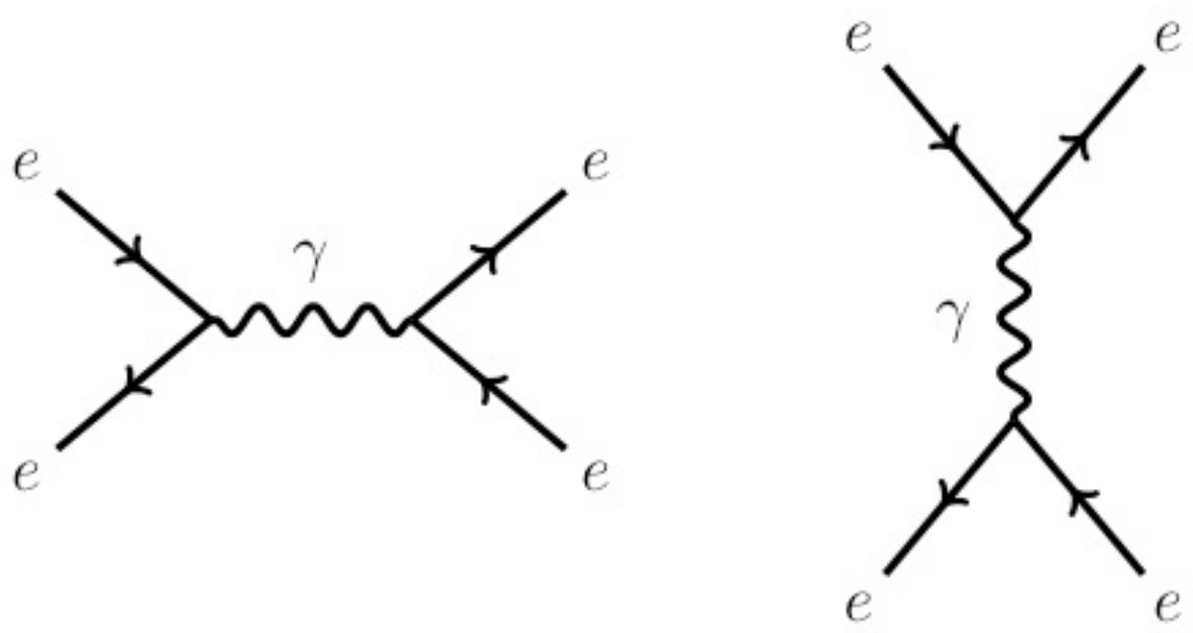

ANTHONY DUNCAN
THE CONCEPTUAL FRAMEWORK OF QUANTUM FIELD THEORY
OXFORD


Mark Srednicki
Quantum Field Theory
CAMBRIDGE


An Introduction to Quantum Field Theory
Michael E. Peskin • Daniel V. Schroeder
ABP

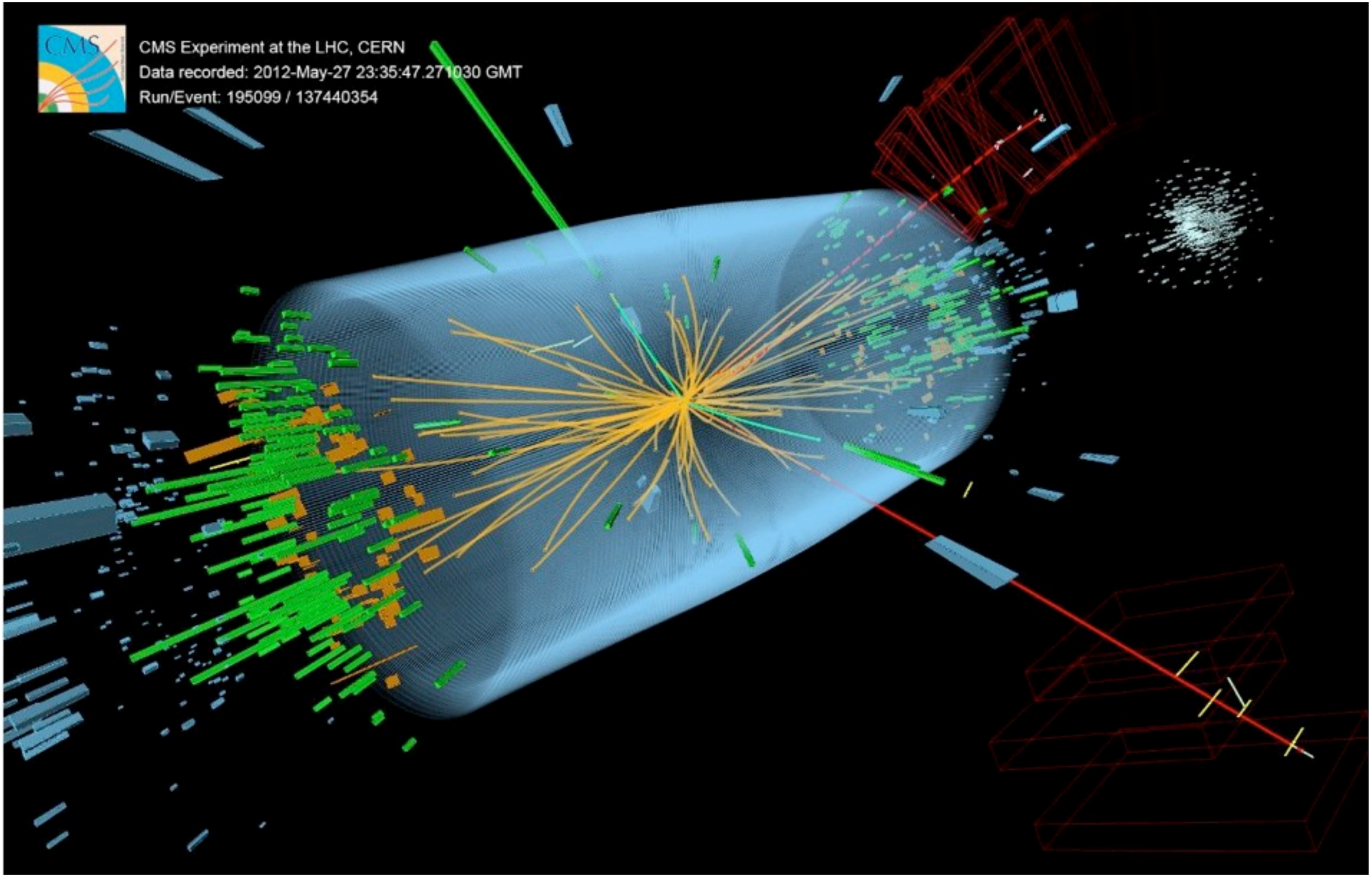

Relativistic Quantum Physics
From Advanced Quantum Mechanics to Introductory Quantum Field Theory
Tommy Ohlsson
CAMBRIDGE

You draw all diagrams with the same external lines; Feynman then tells you the amplitude



We teach these rules to our Part III students

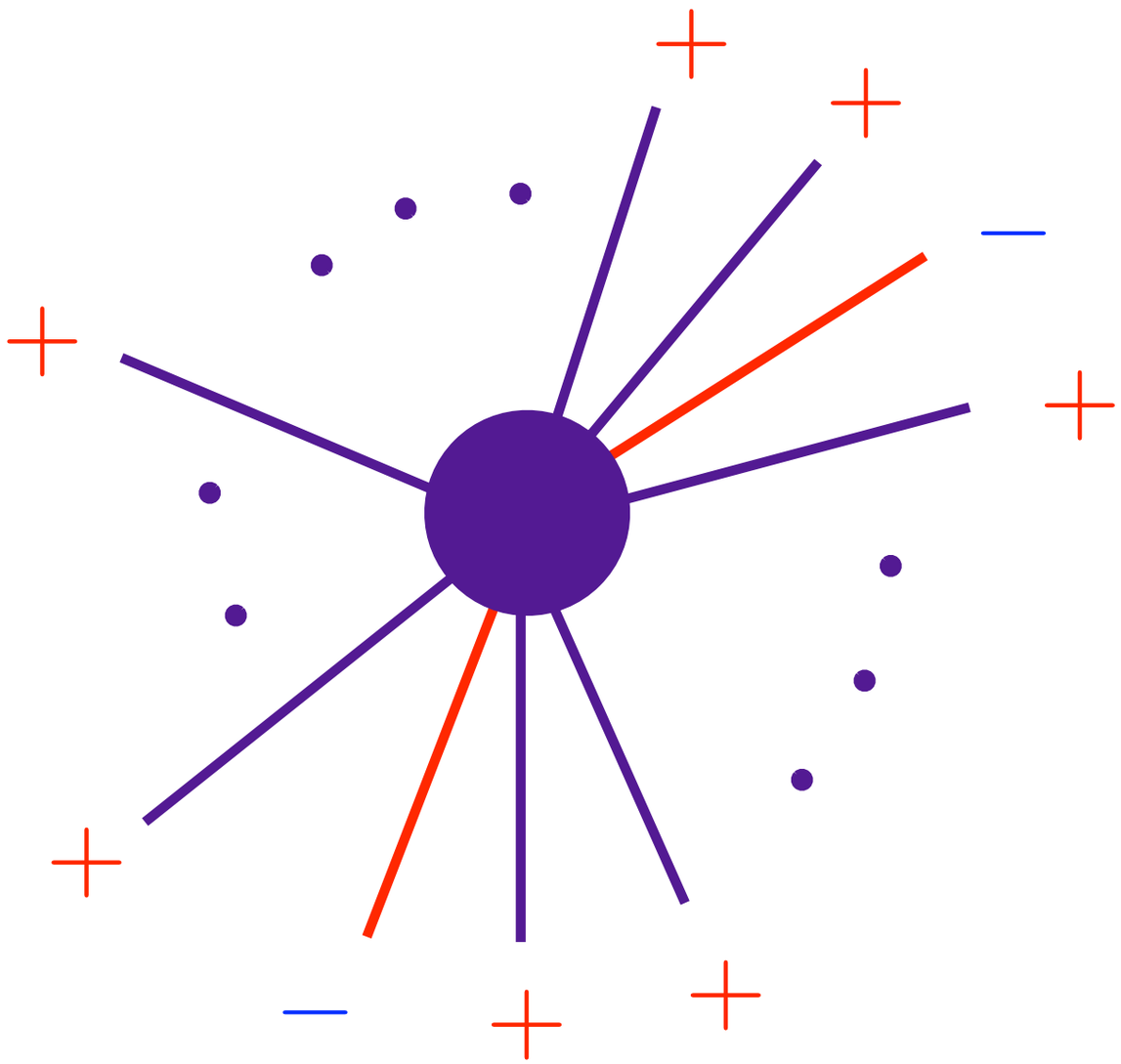
- the reason they work was explained by Freeman Dyson in the late 1940s


CMS Experiment at the LHC, CERN
Data recorded: 2012-May-27 23:35:47.271030 GMT
Run/Event: 195099 / 137440354

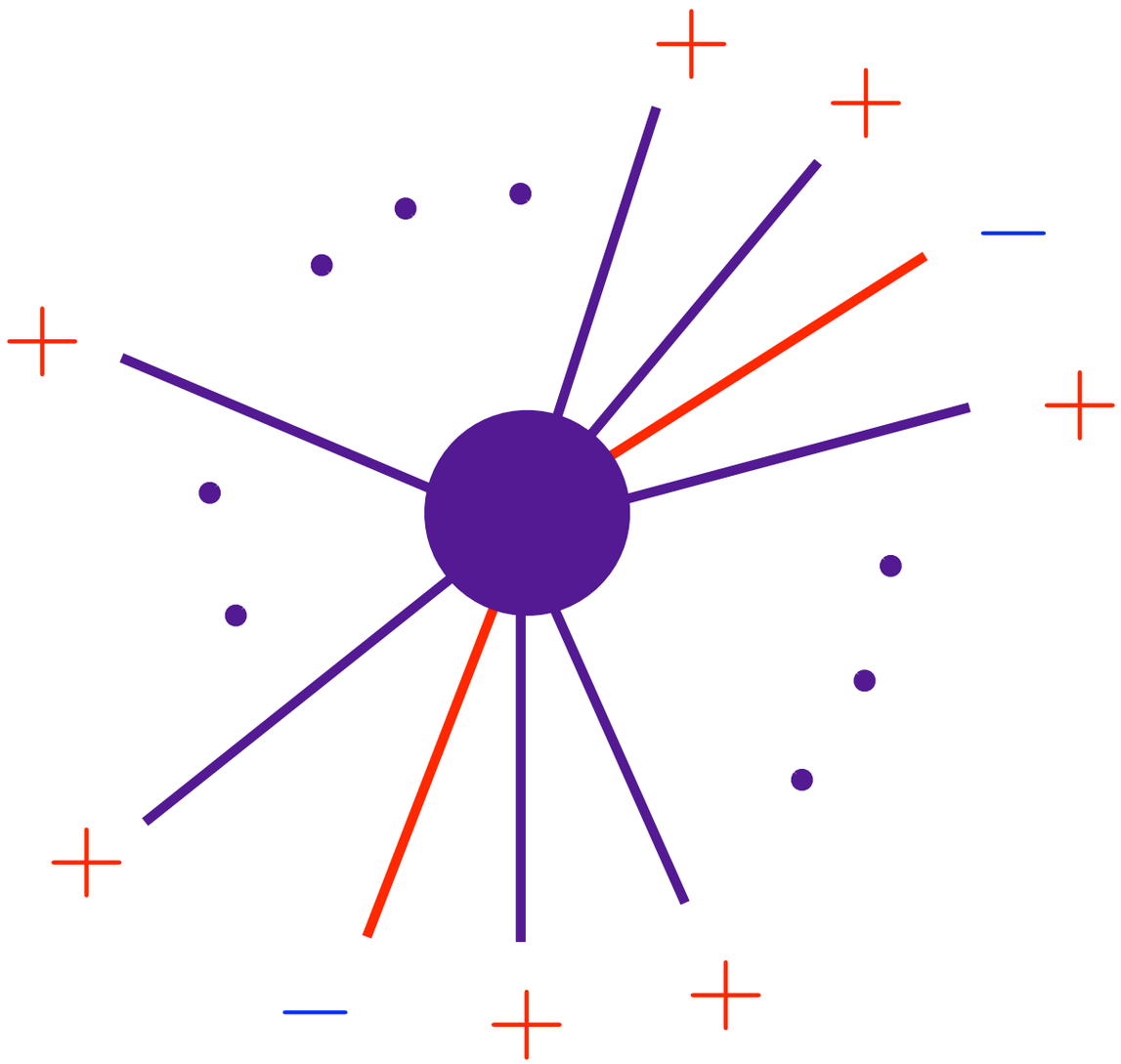
Result of a Feynman diagram calculation for 2 particles producing a third in a QFT (YM):

$$k_1 \cdot k_4\, \varepsilon_2 \cdot k_1\, \varepsilon_1 \cdot \varepsilon_3\, \varepsilon_4 \cdot \varepsilon_5$$

+ seventeen more pages!



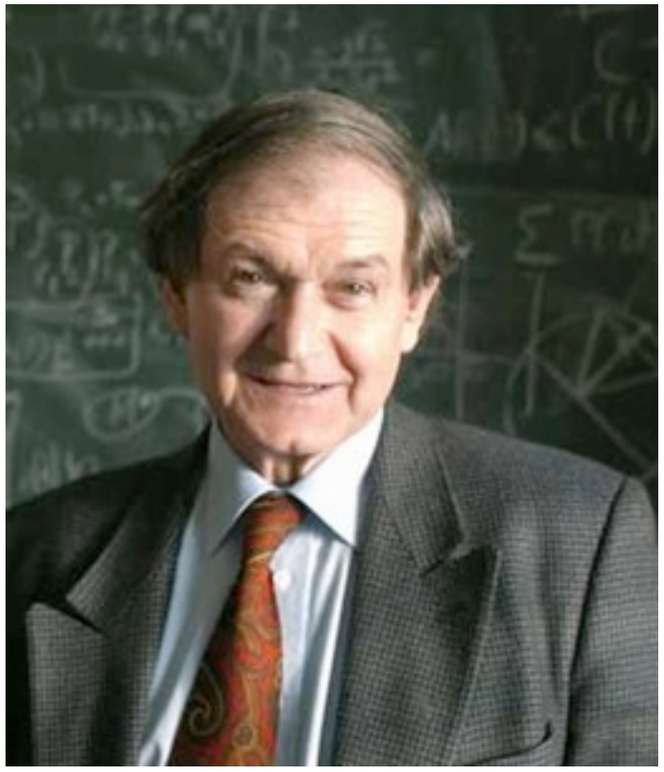
$$\frac{\langle ij\rangle^4\,\delta^4(\sum p_i)}{\langle 12\rangle\,\langle 23\rangle\,\cdots\,\langle n1\rangle}$$



$$\frac{\langle ij\rangle^4\,\delta^4(\sum p_i)}{\langle 12\rangle\,\langle 23\rangle\,\cdots\,\langle n1\rangle}$$

Why is the answer so simple?

Twistor Theory

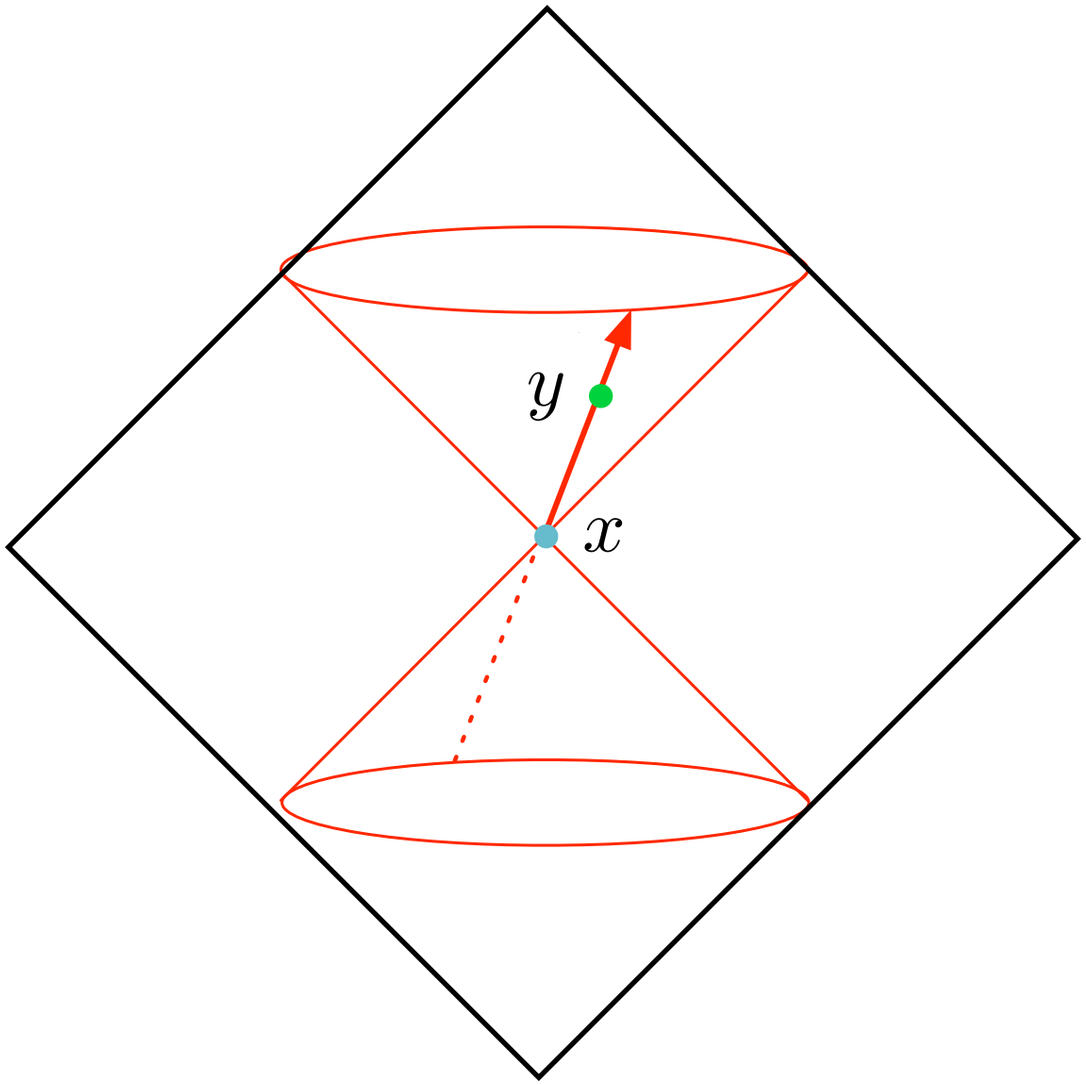


Twistors were developed in the 1970s by Penrose, intended as a new framework for physics

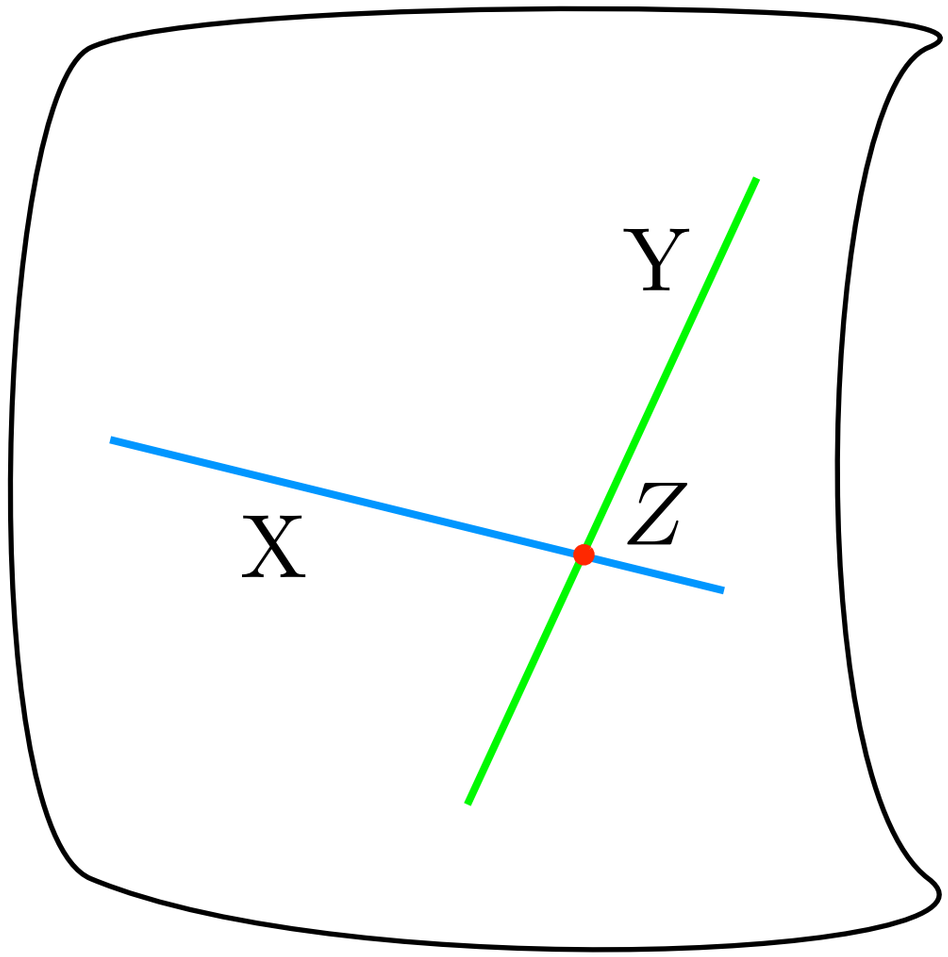
He wished to promote causal relationships between events above the events themselves

Thanks to Atiyah, Hitchin, Ward & many others they quickly found application in *mathematics*, but physics was slow to catch on...

Space-time



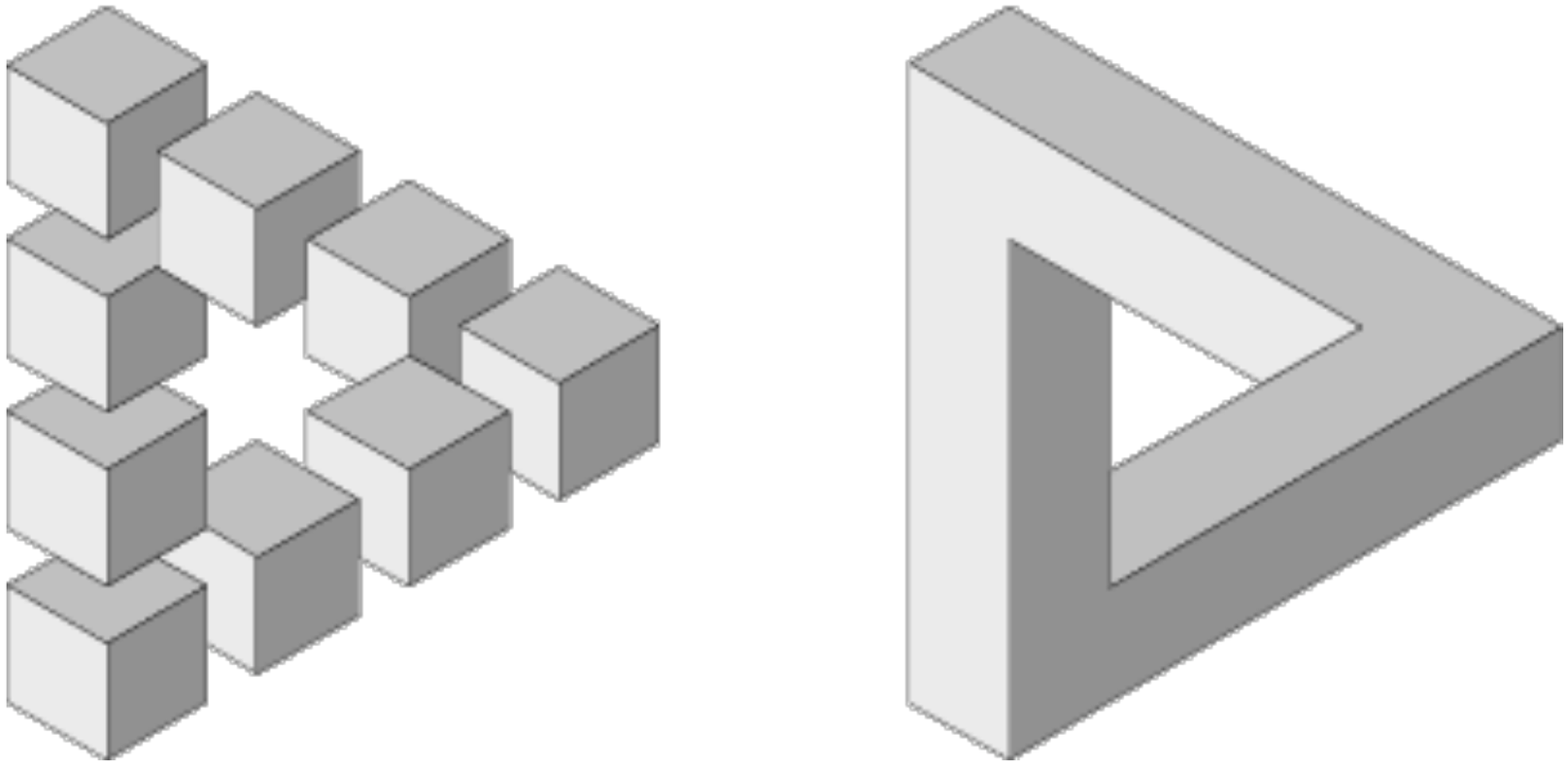
Twistor space



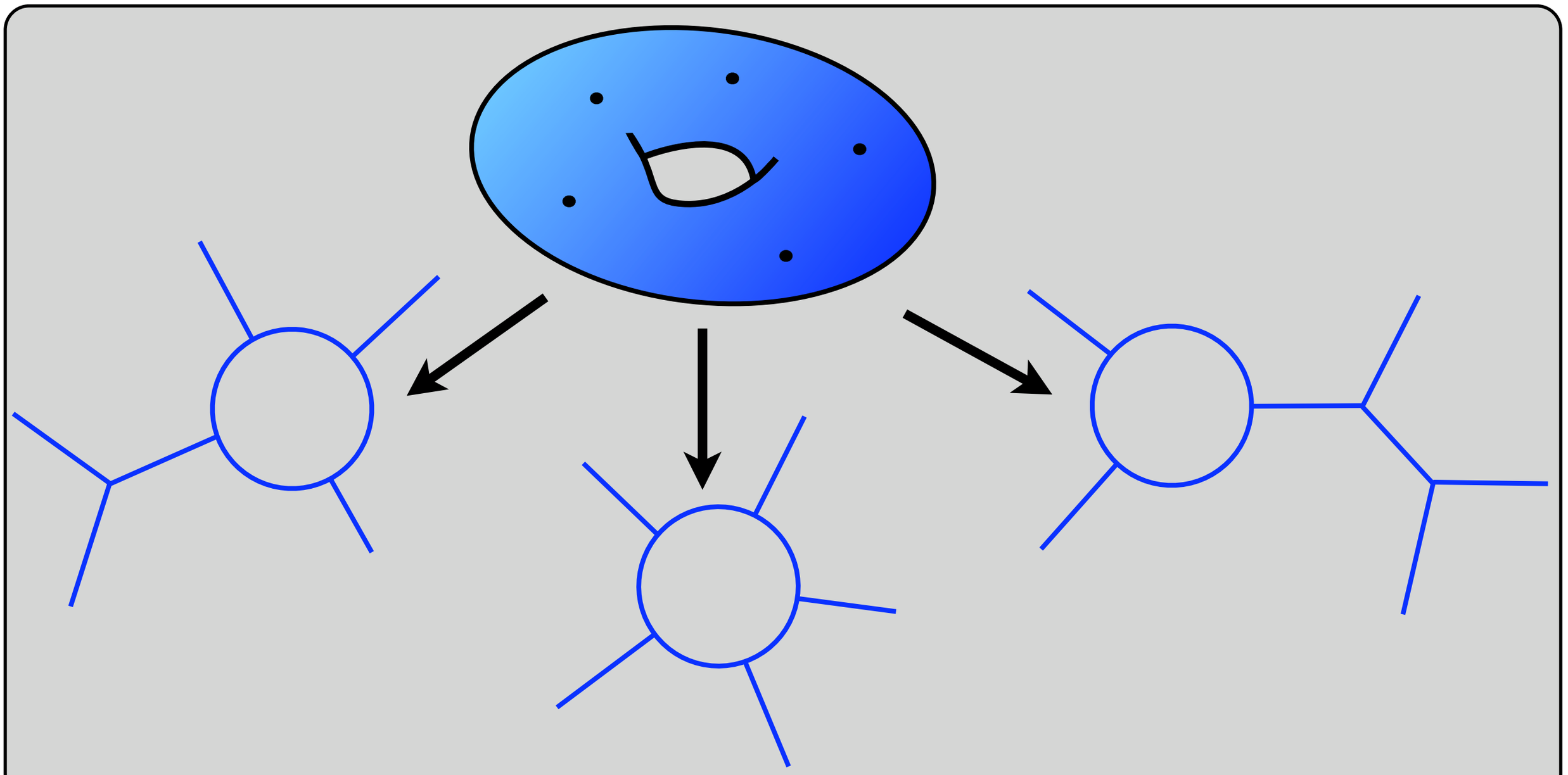
Point in space-time ⟷ Sphere in twistor space

Separation is light-like ⟷ Two spheres intersect

Physical objects are encoded in *global* properties of objects in twistor space



Physics is not described by point-like objects on twistor space: no “particles”

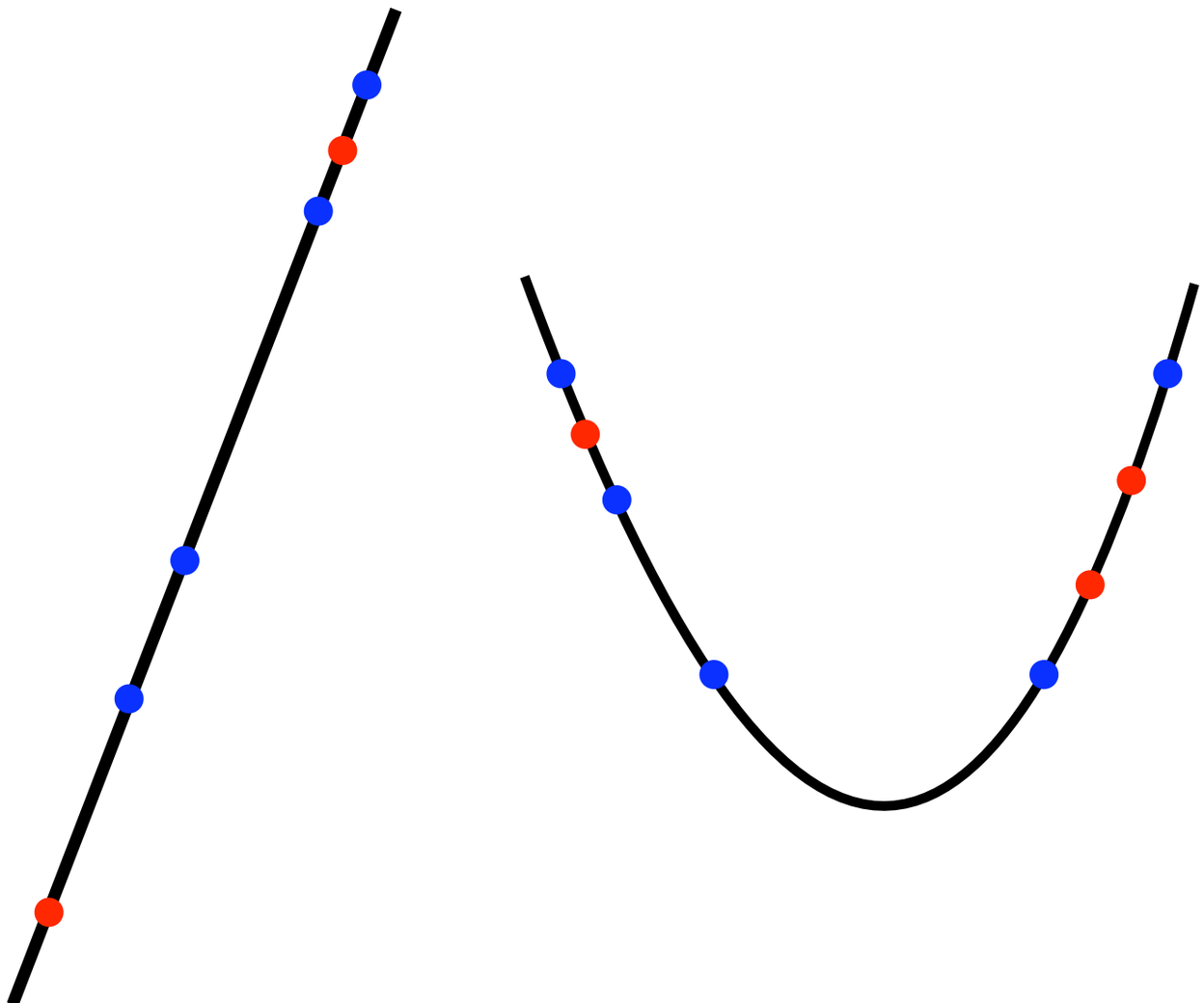


Replacing many Feynman diagrams with one single object is common in string theory, but at a high price:

10 dimensions

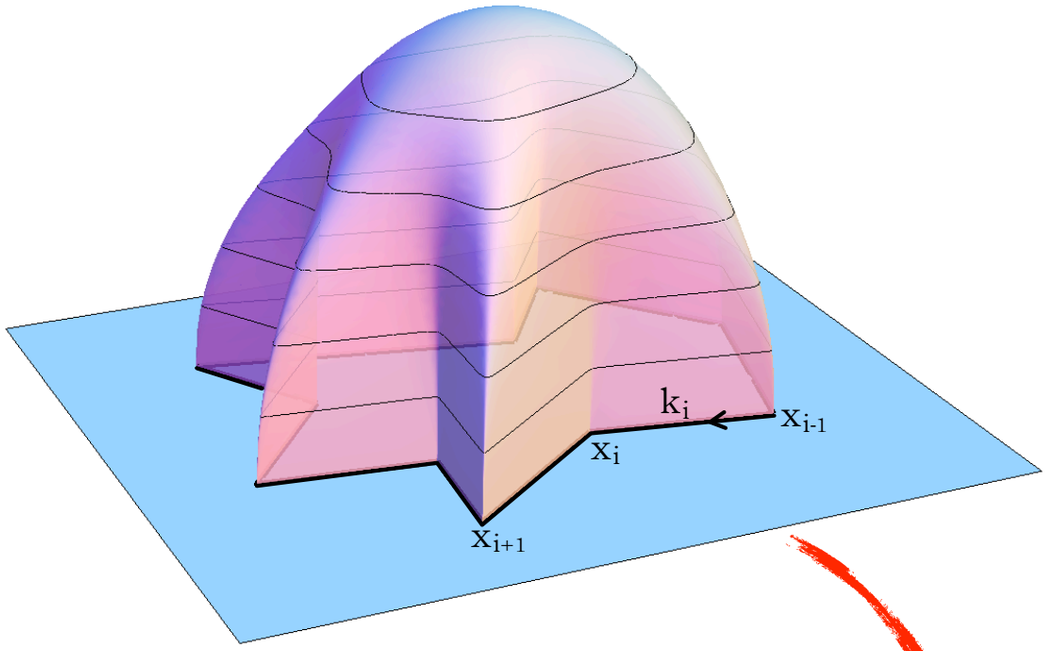
Infinitely many new types of particle

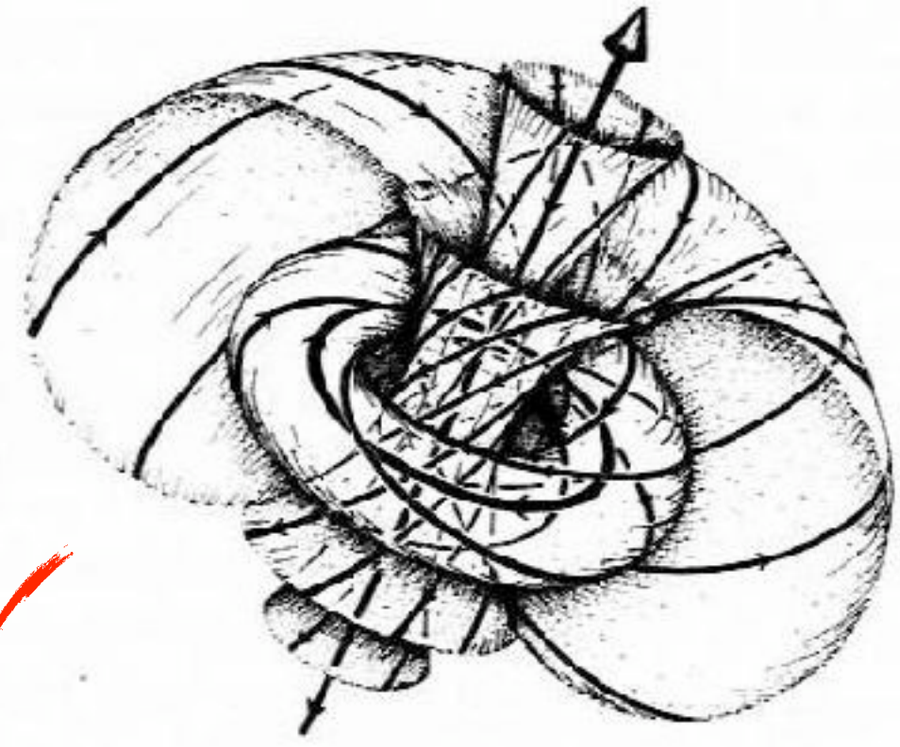
In late 2003, Witten realized that a string theory *in twistor space* was just what was needed

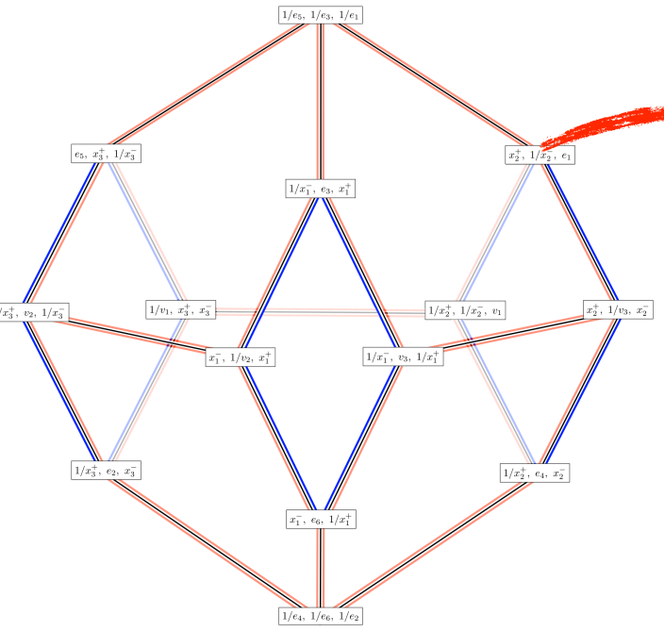


Only 3+1 dimensions

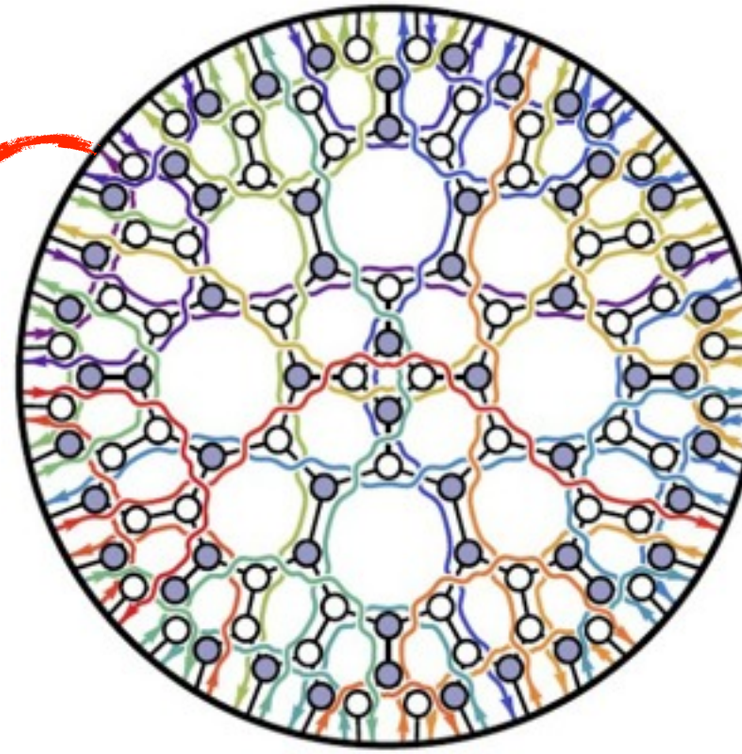
Only particles we've seen







Scattering Amplitudes



Vast increase in technical power

New structures at the heart of QFT