

The PENTAQUARK

is it magic?

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July 2015

- 1 - Reminder: quarks, colour, J/ψ
- 2 - Bound states of quarks - simple and complex states
- 3 - Why to search for a pentaquark?
- 4 - Production of b quarks in LHCb
- 5 - The decay of a Λ_b
- 6 - Some of the observations
- 7 - The analysis and interpretation

REMINDER FROM LECTURES

SU(3) - Classification scheme based on 'quarks'

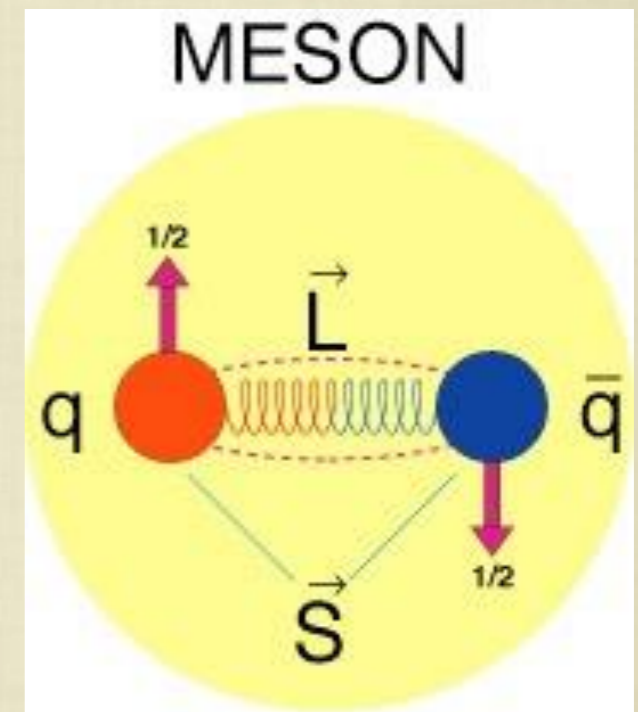
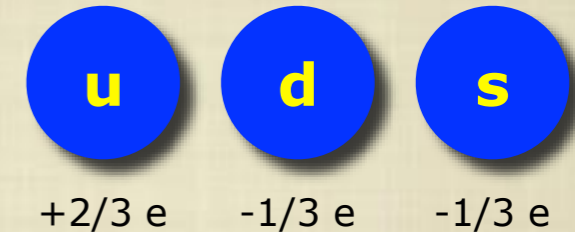


Fig. 6.35 Murray Gell-Mann (b.1929).

Gell-Mann, 1963

(G. Zweig, 1963, CERN)

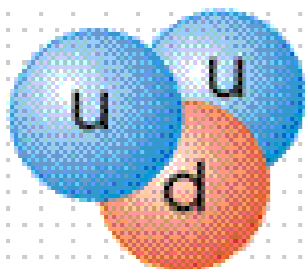
- 1) 3 types of "quarks" : up, down, strange
- 2) Carry electric charges: $+2/3$, $-1/3$, $-1/3$
- 3) Appear in combinations:
 Meson = quark+antiquark
 Baryon = quark(1) + quark(2) + quark(3)



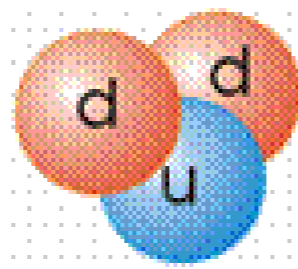
$$\begin{array}{c}
 u \\
 d \\
 s
 \end{array}
 +
 \begin{array}{c}
 \bar{u} \\
 \bar{d} \\
 \bar{s}
 \end{array}$$

3 x 3 = 8 + 1 combinations

The Proton



The Neutron



PARTICLE SPECTRUM

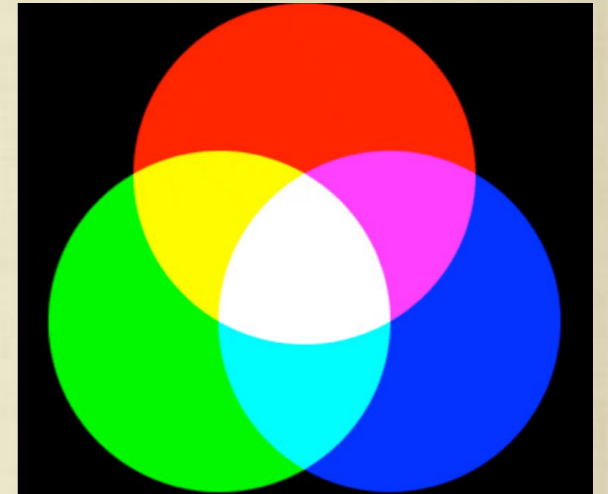
Quantum Chromo Dynamics

this has nothing to do with our visible colours, just an analogy

Theory constructed in analogy to QED

QCD: 3 different charges ("colour charge") [red, green, blue]*

'Strong force' between quarks is transmitted by (8) gluons



Dogma of QCD: Only colour-neutral bound states are allowed

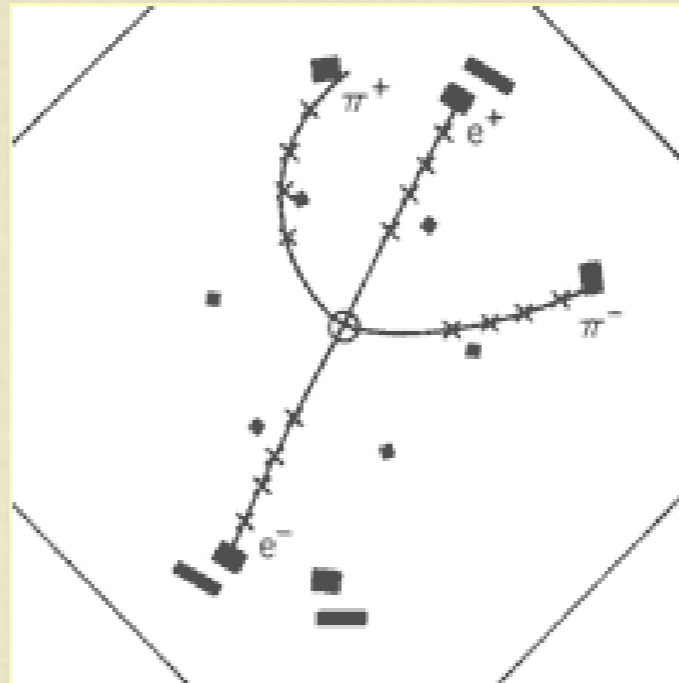
MESONS = Quark-Antiquark

BARYONS = 3-Quark states

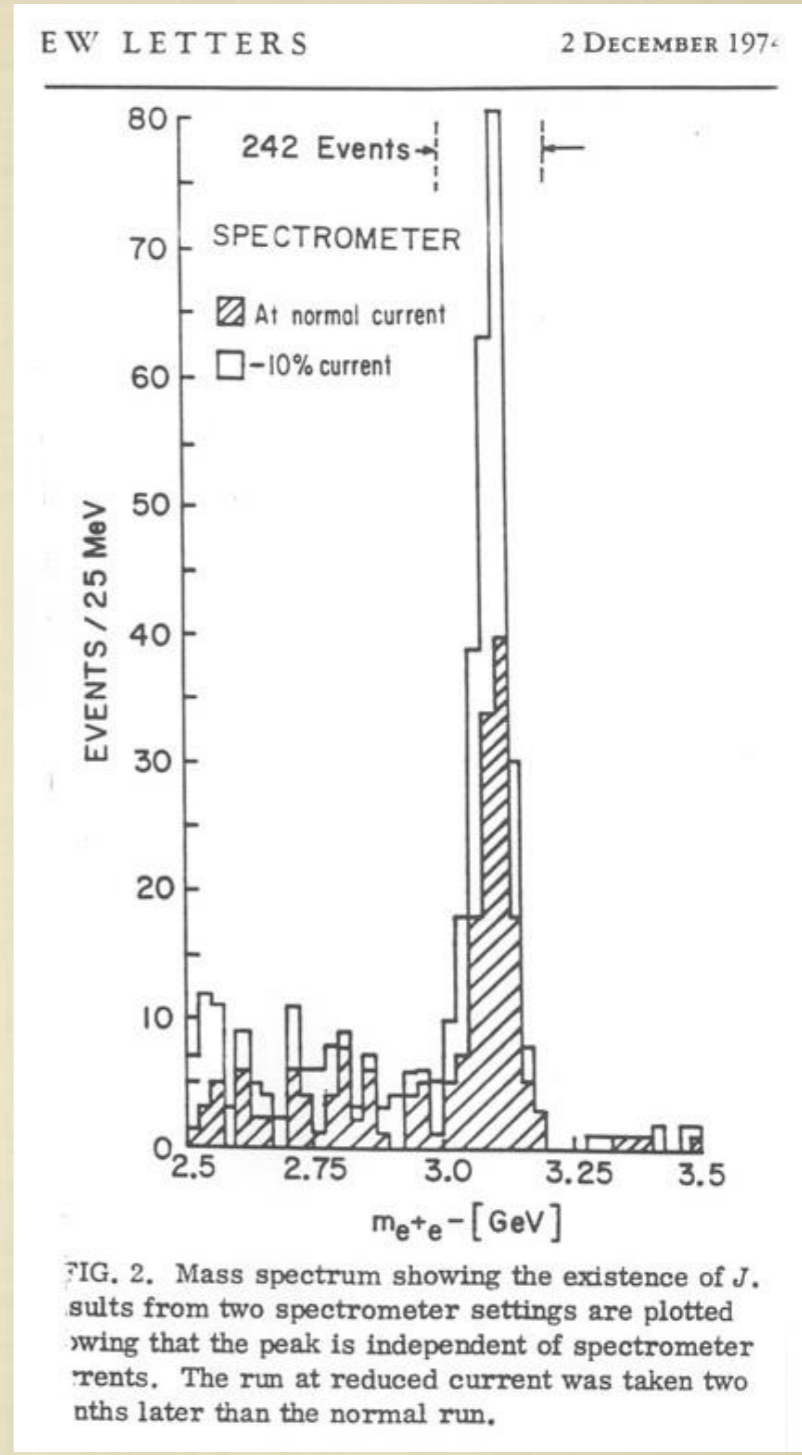
Discovery of the 'charm' quark in 1974

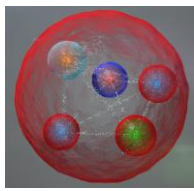
NOVEMBER REVOLUTION (11 November 1974)

'Psi' at SLAC (Burt Richter)
 'J' at Brookhaven (Sam Ting)
 Compromise: J/Psi



"Extremely" long lifetime ($\sim 10^{-20}$ sec)
 Decay only possible through electroweak interaction





2 - Bound states of quarks - simple and complex states

QCD: only 'white' states can exist

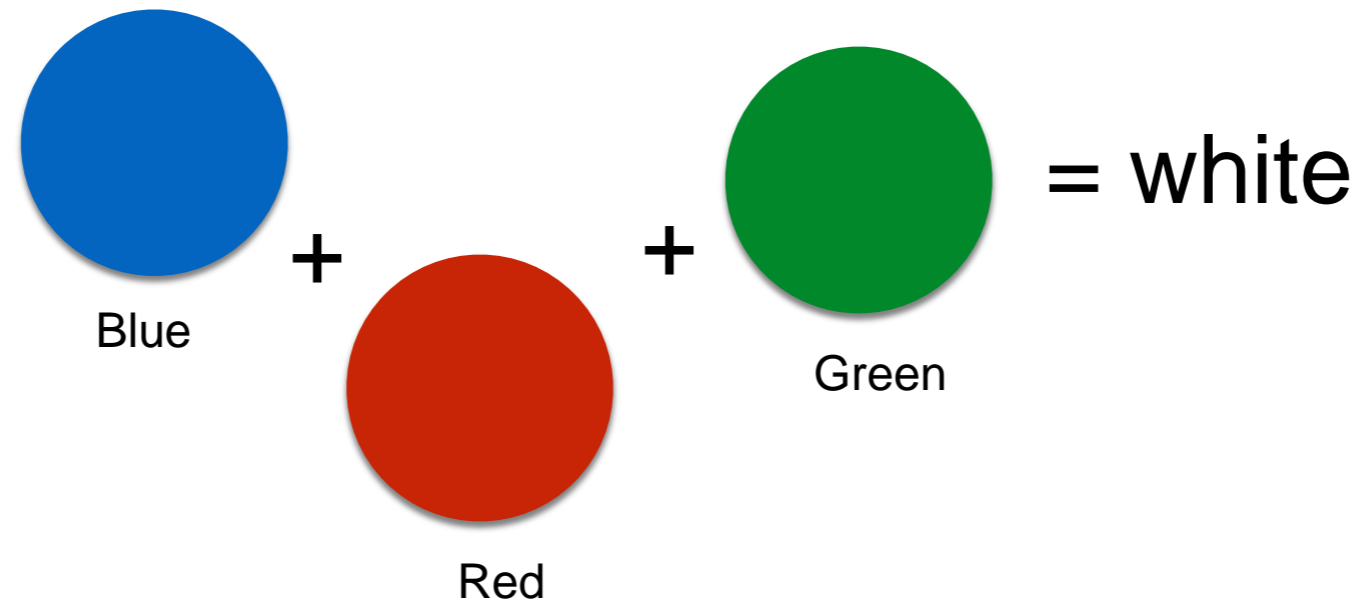
"50 shades of white"

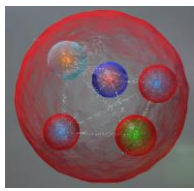
MESON



SIMPLEST STATES

BARYON

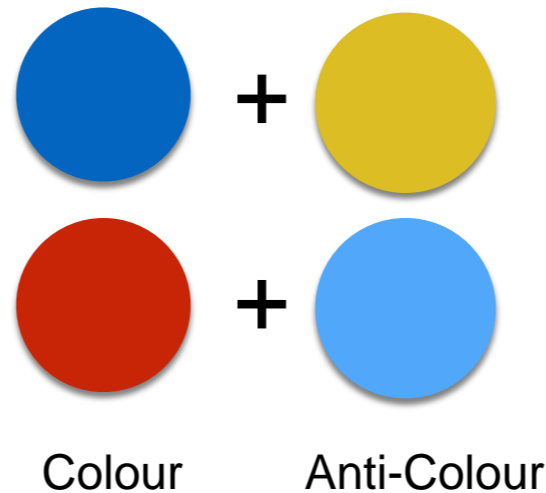




2 - Bound states of quarks - simple and complex states

More complex bound states also allowed:

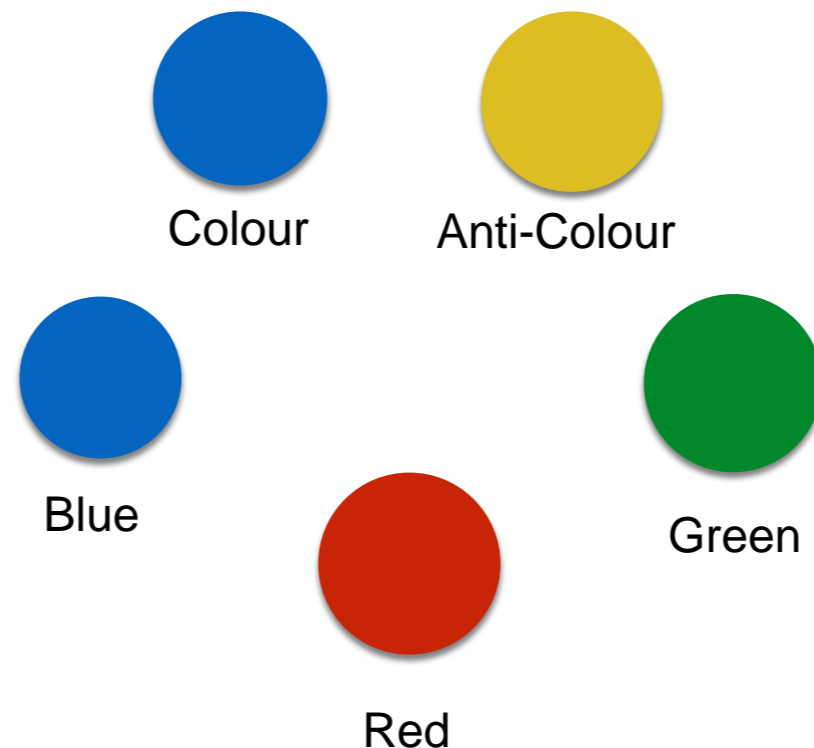
Four quark state



= white

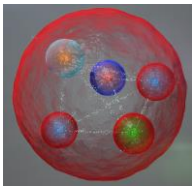
COMPLEX BOUND STATES

Five quark state



= white

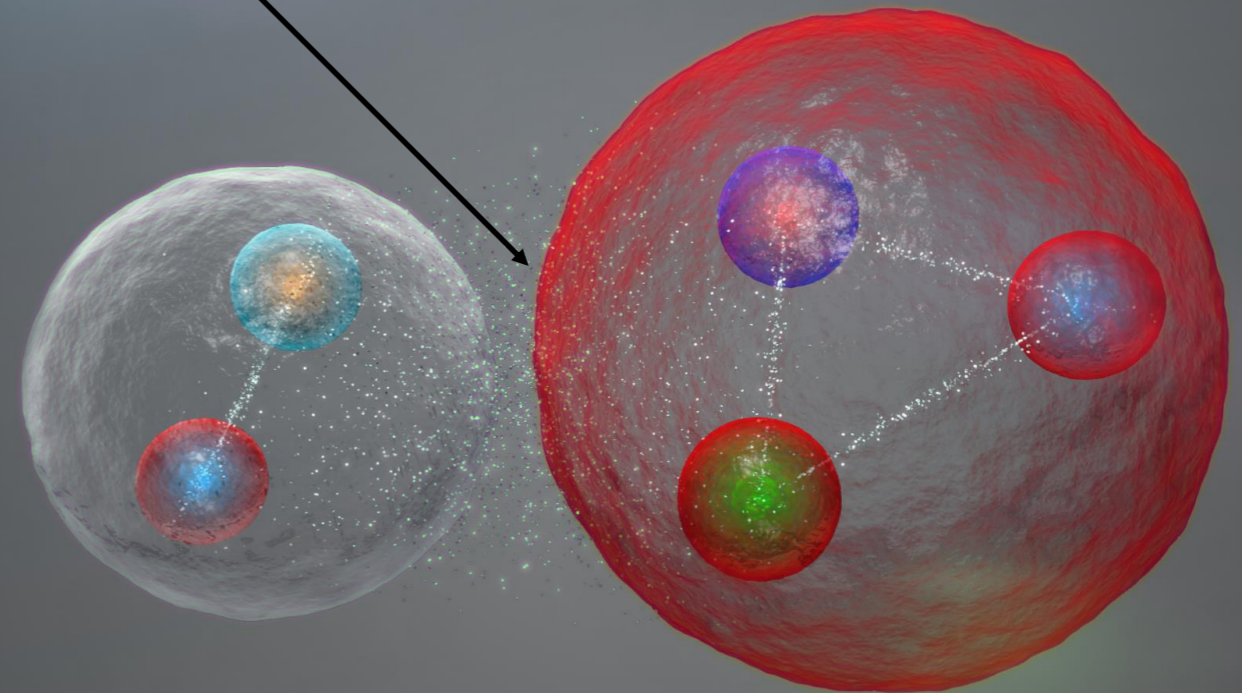
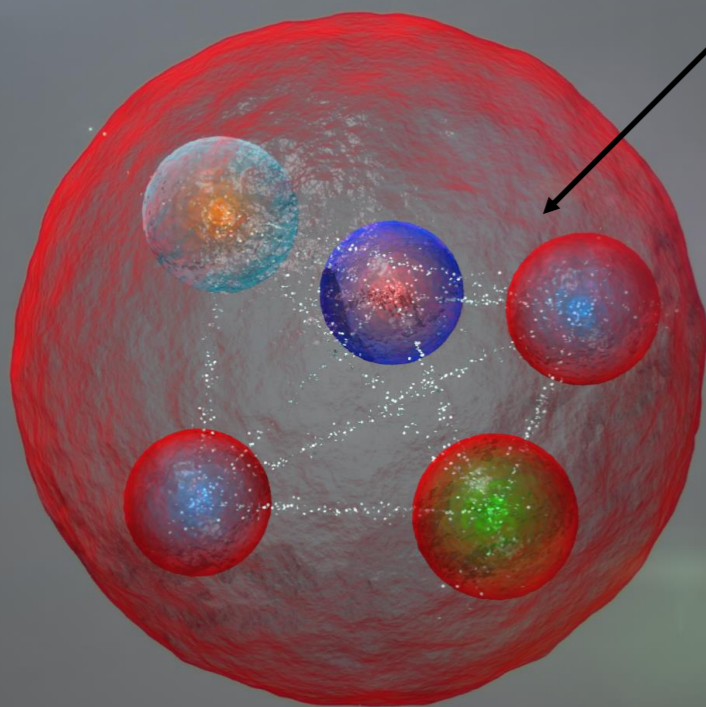
“Pentaquark”

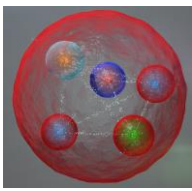


3 - Why to search for a pentaquark?

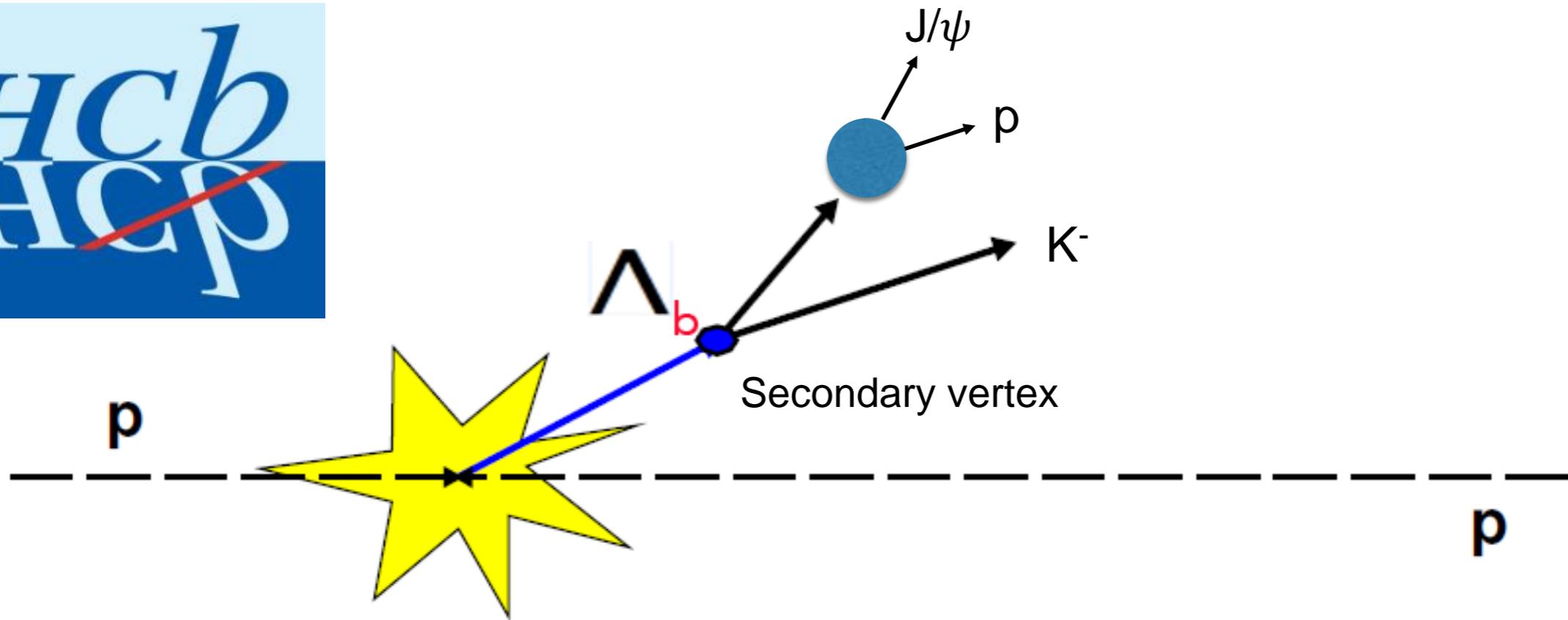
Better understanding of QCD at low energy

This ... or this ?



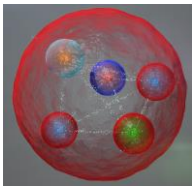


4 - Production of b quarks in LHCb



Lifetime Λ_b : $1.4 \cdot 10^{-12}$ sec \sim 435 μ m

Mass Λ_b : 5619.5 MeV



5 - The decay of a Λ_b

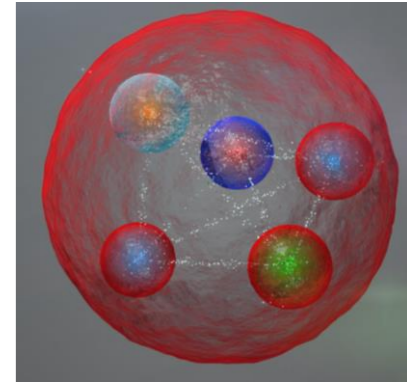
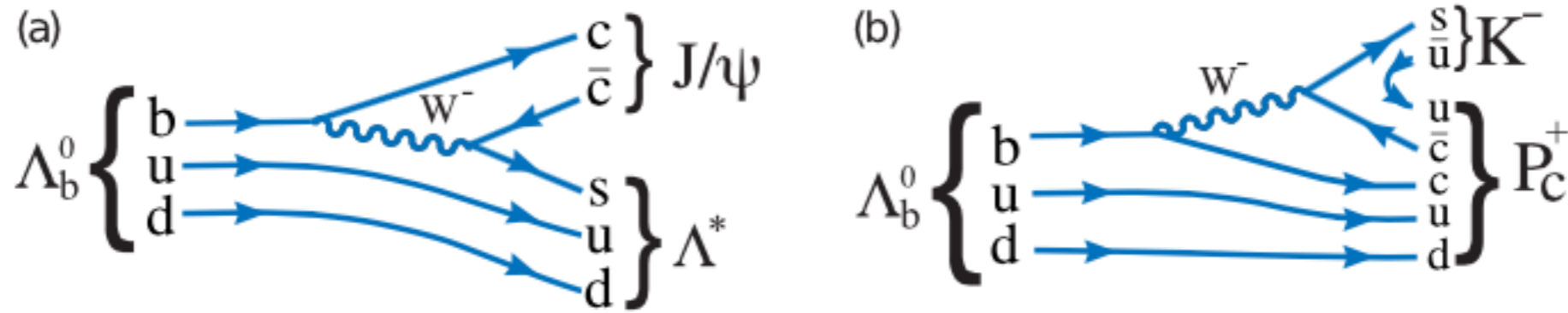


Figure 1: Feynman diagrams for (a) $\Lambda_b^0 \rightarrow J/\psi \Lambda^*$ and (b) $\Lambda_b^0 \rightarrow P_c^+ K^-$ decay.

Mass Λ_b : 5619.5 MeV

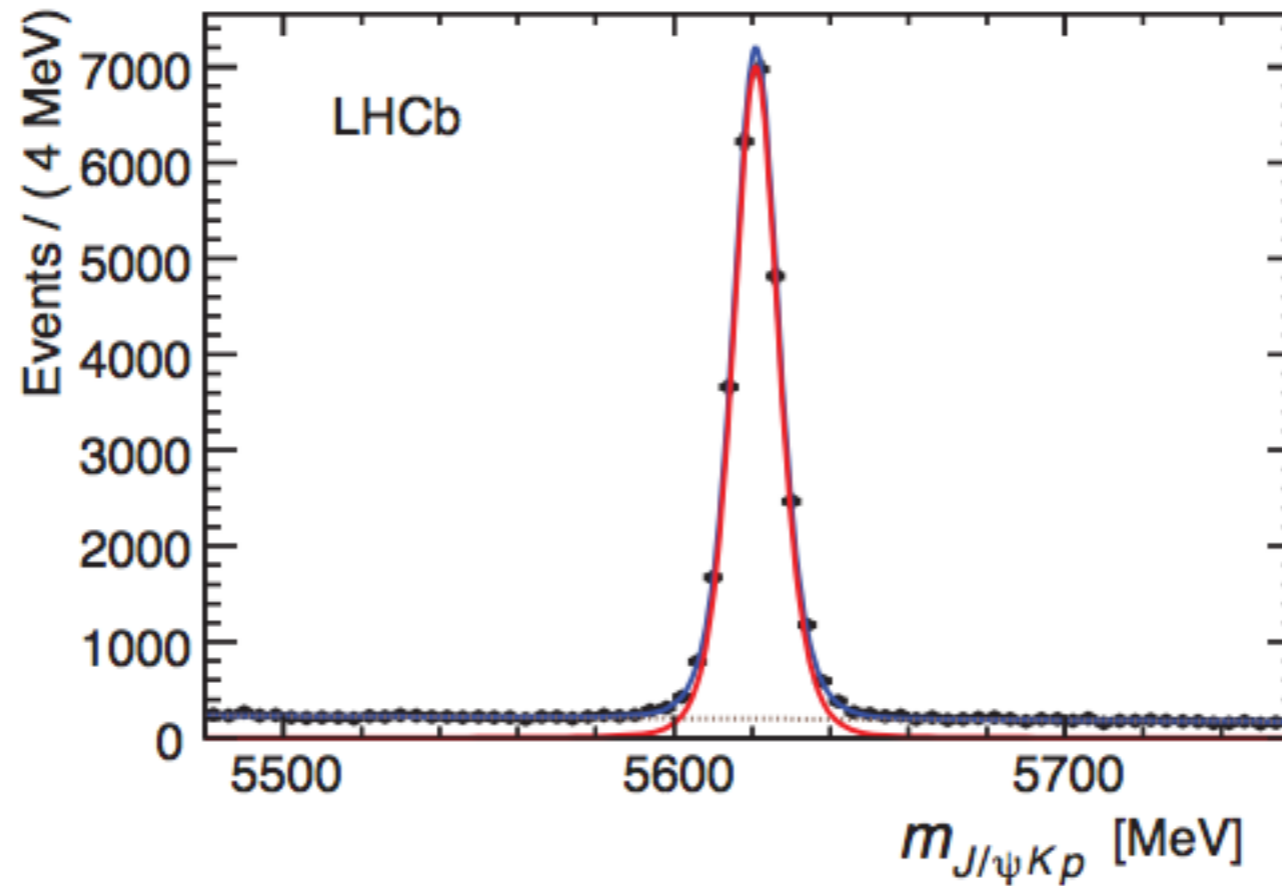
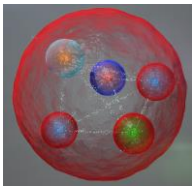
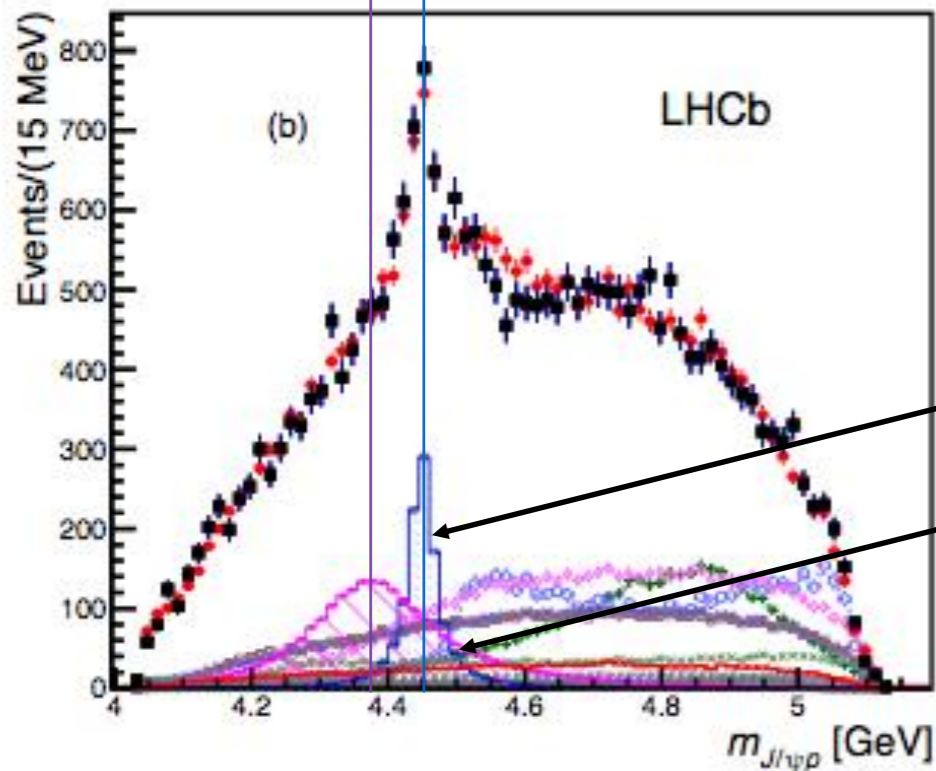
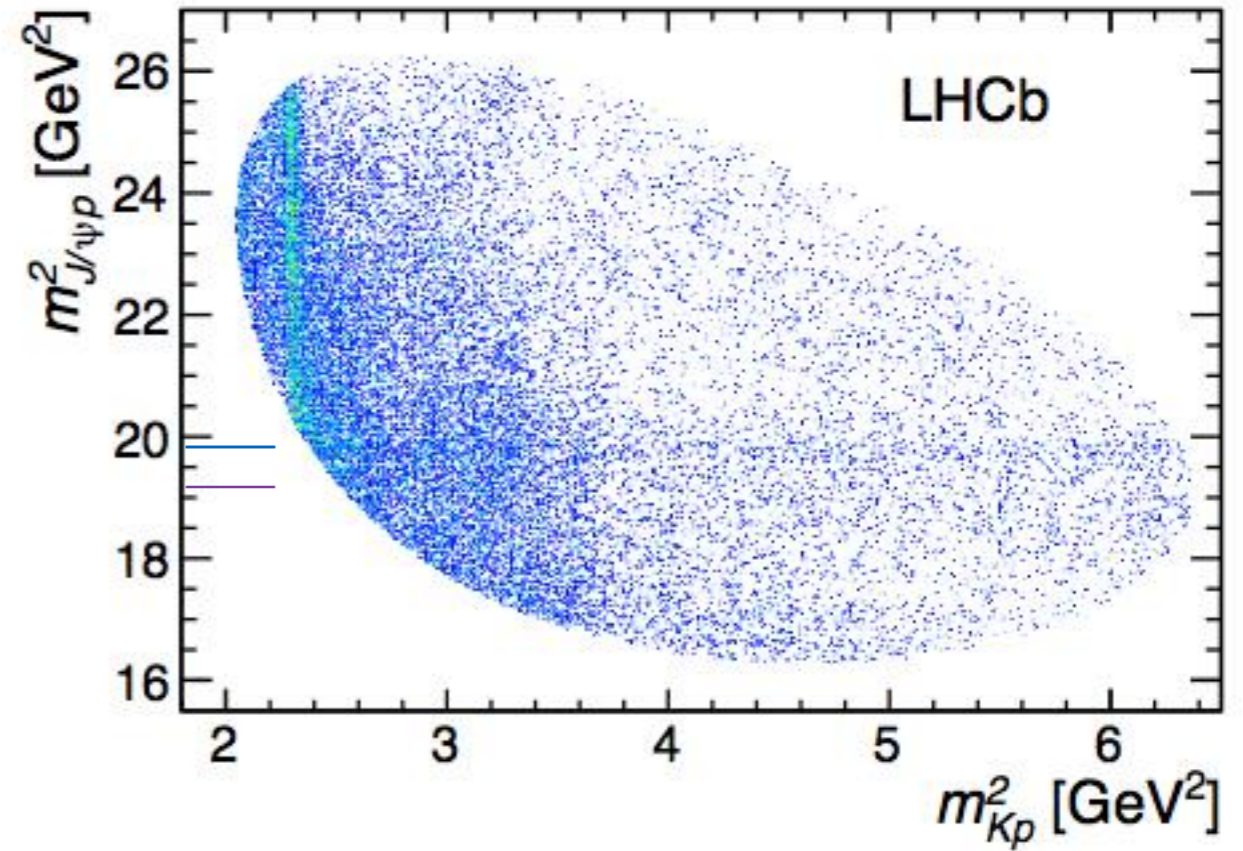
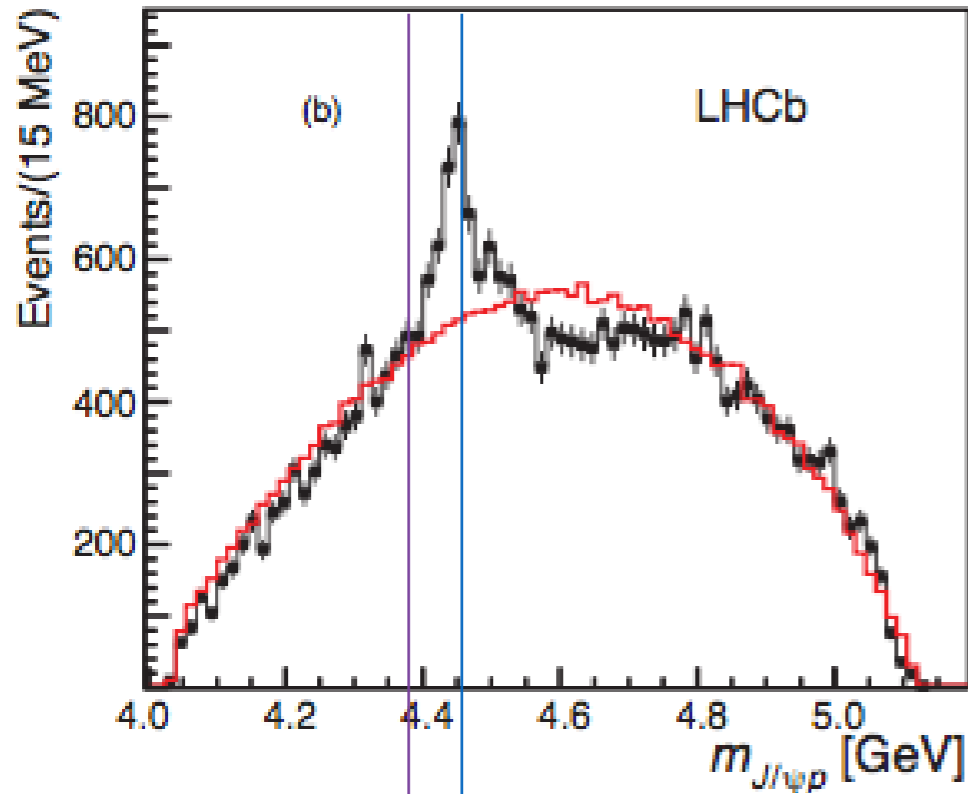


Figure 4: Invariant mass spectrum of $J/\psi K^- p$ combinations, with the total fit, signal and background components shown as solid (blue), solid (red) and dashed lines, respectively.

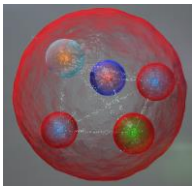


6 - Some of the observations

$M = 4380 \text{ MeV}$, Width = 205 MeV $M = 4450 \text{ MeV}$, Width = 40 MeV



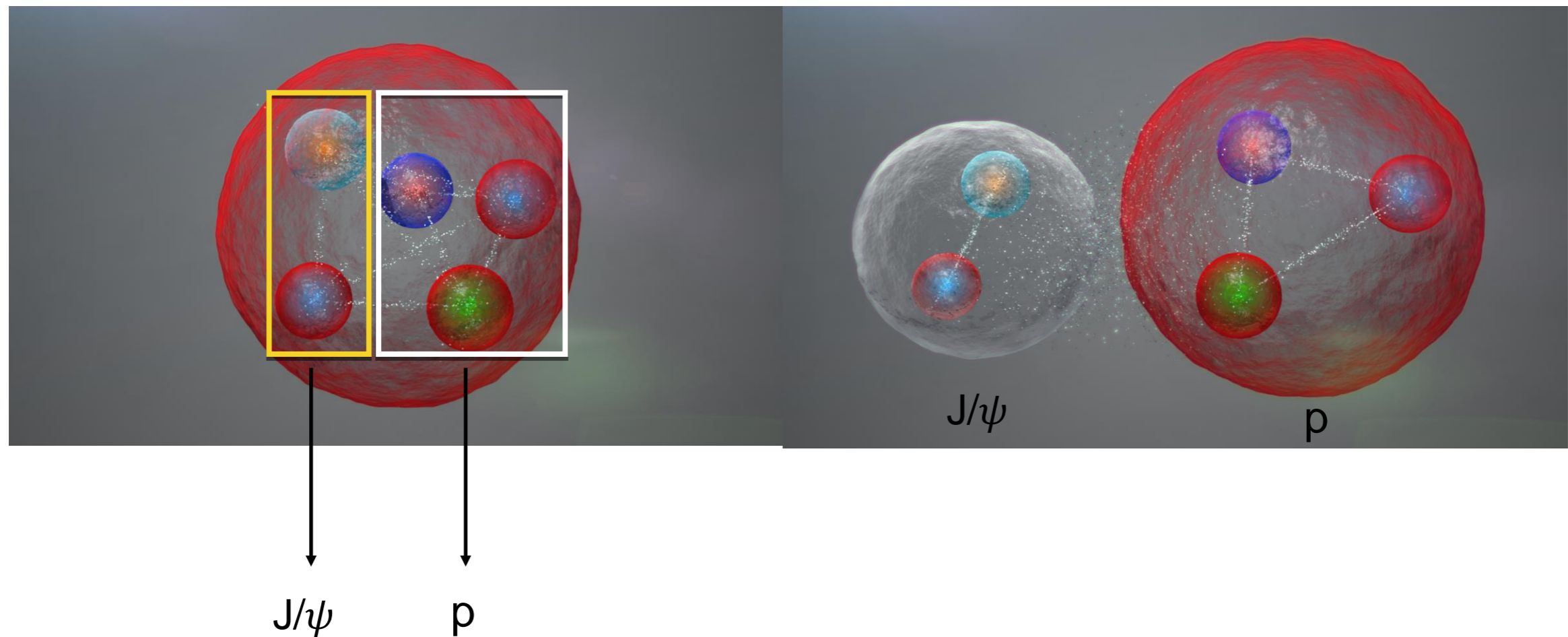
Two Penta-Quark states



7 - Analysis and interpretation

Complex partial wave analysis based on “Dalitz plot”

Best fit results: Spin 3/2 (broad state), Spin 5/2 (narrow state)



More studies are necessary to find out more about these states.