

Strategies to Hunt for New Physics with Strange Beauty Mesons



Robert Knegjens

Particle Physics



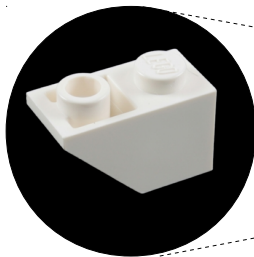
The Periodic Table of the Elements

1 H Hydrogen 1.01																	2 He Helium 4.00
3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.61	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xenon 131.29
55 Cs Cesium 132.91	56 Ba Barium 137.33	57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.97	
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	90 Th Thorium (232.04)	91 Pa Protactinium (231.04)	92 U Uranium (238.03)	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258.10)	102 No Nobelium (259)	103 Lr Lawrencium (262)	

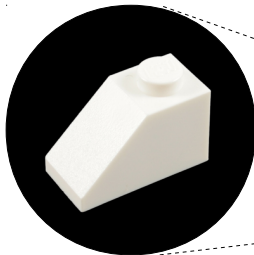
Legend:

- Atomic Number
- Element Symbol
- Element Name
- Average Atomic Mass

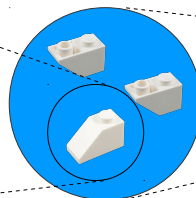
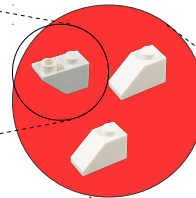
“up” quark



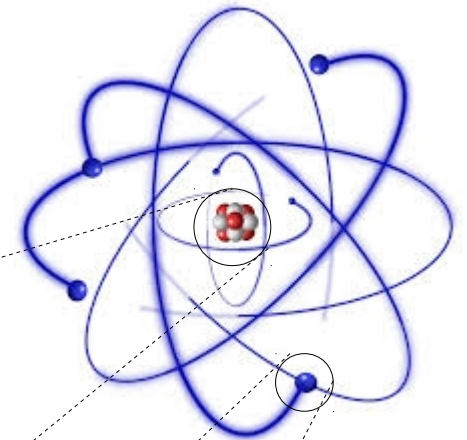
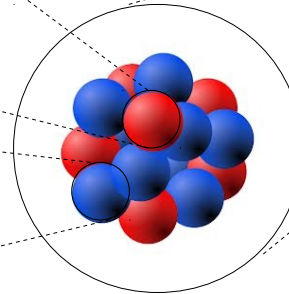
“down” quark



(neutron)



(proton)



electron

The Standard Model

Bosons



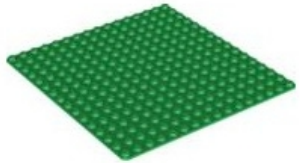
photon
(electromagnetism)



W boson
(weak nuclear force)



gluon
(strong nuclear force)



Higgs boson

Quarks



up



charm



top



down



strange



beauty

Leptons



electron



muon



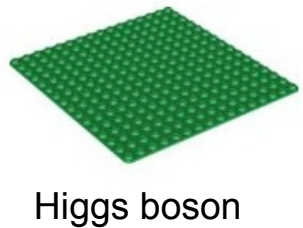
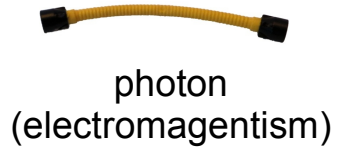
tau



neutrinos

The Standard Model

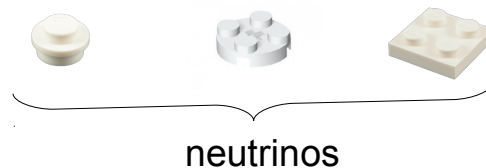
Bosons



Quarks



Leptons



“matter”

Electric Charge

+2/3

-1/3

-1

0

Anti-quarks



Anti-leptons



“antimatter”

Electric Charge

-2/3

+1/3

+1

0

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

Paul Dirac (1928)



MATTER

ANTI-MATTER

S. Harris

The
Standard Model

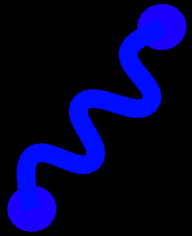
◆ ~1975

† ?

?

New Forces

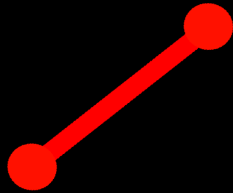
NEW
FORCES



Quedo?

New Matter

NEW
MATTER



Quedo?

“New Physics”

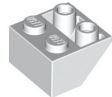
Quark flavours



up



charm



top



down



strange



beauty

Change flavour via **weak force**



in Standard Model



Behave asymmetrically
(violate "CP symmetry")

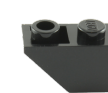


up

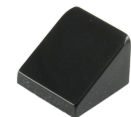


beauty

\neq



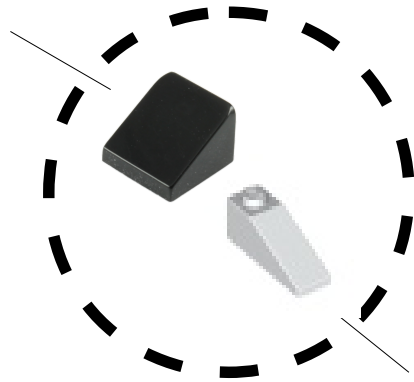
anti-up



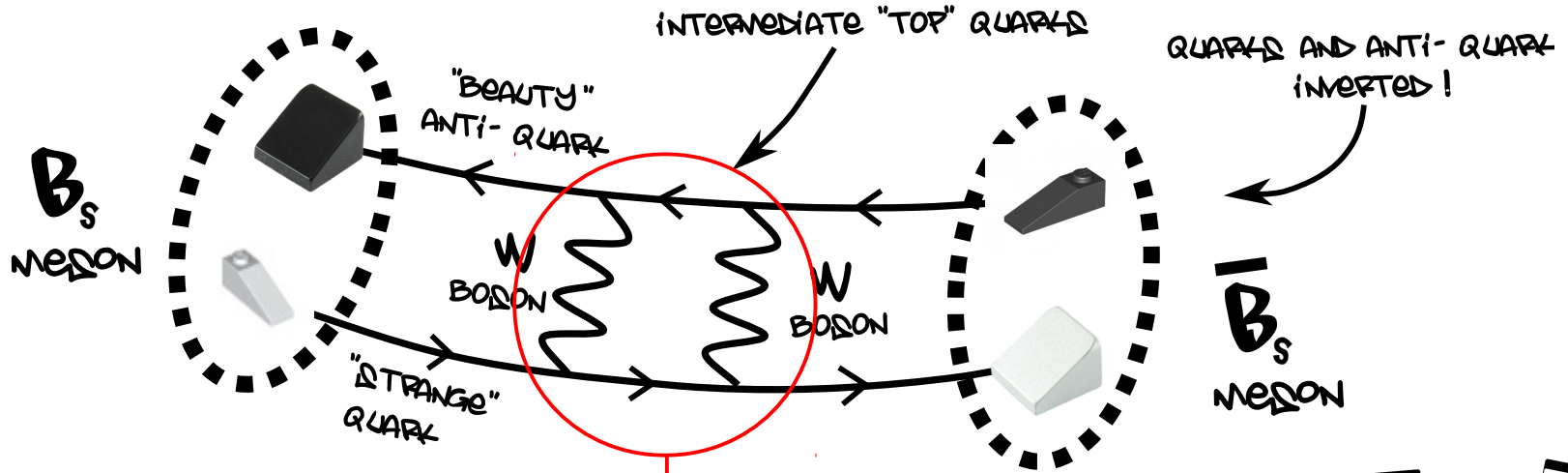
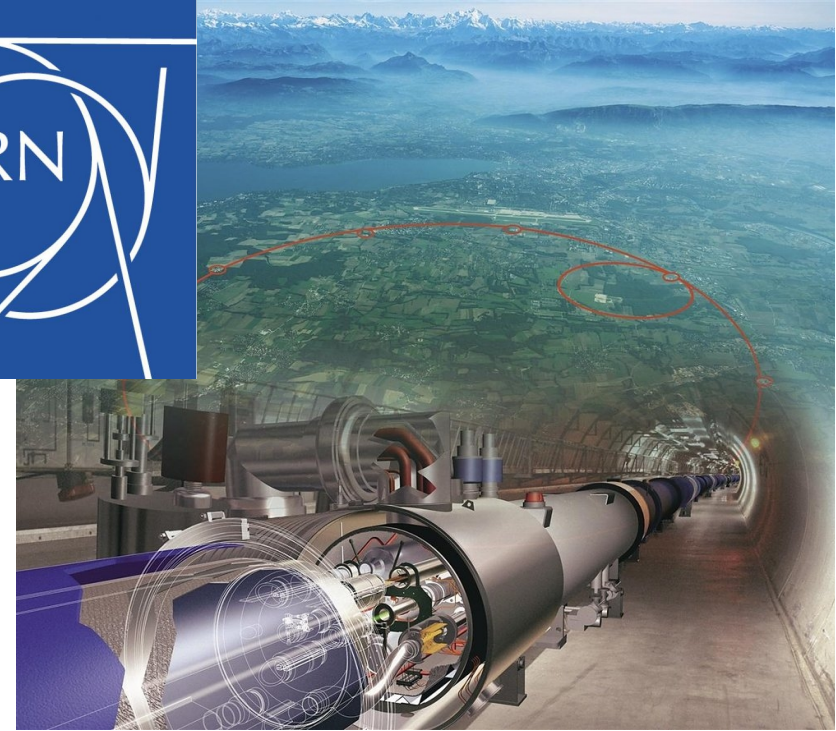
anti-beauty

Strange Beauty Mesons

Beauty antiquark

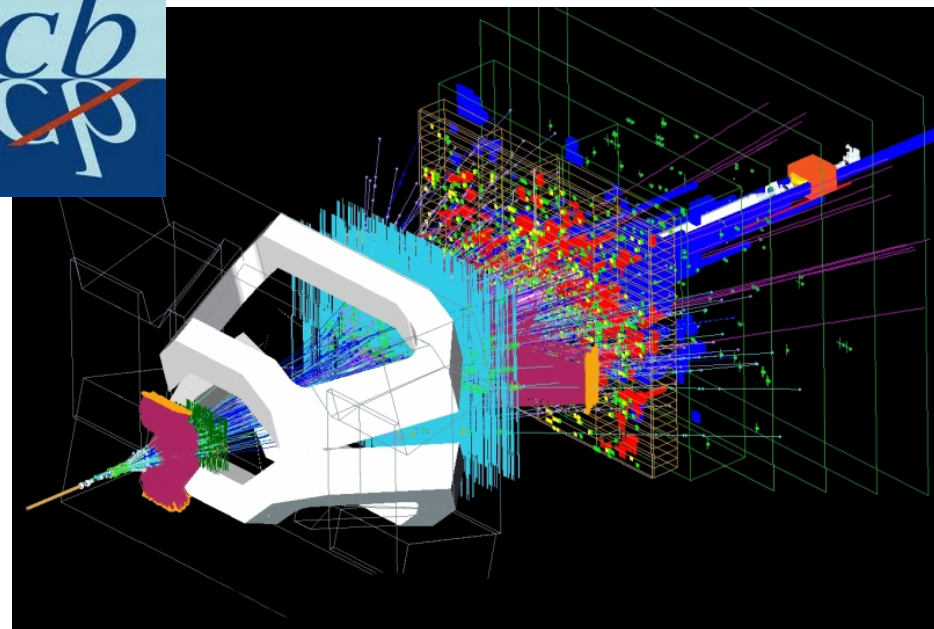


Strange quark



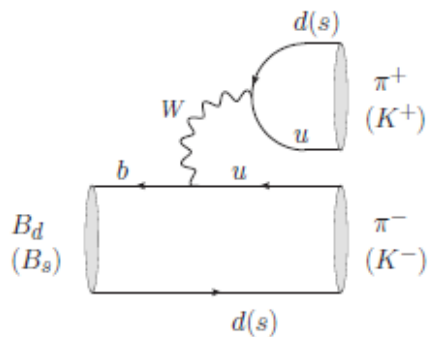
New Physics?



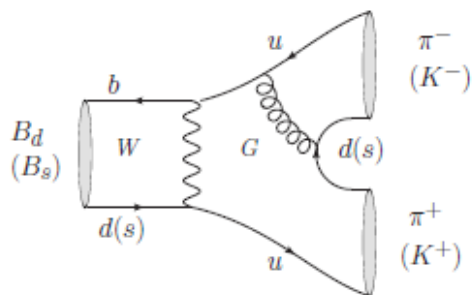


Challenging to **experimentally** measure ...

Current-current (cc) :

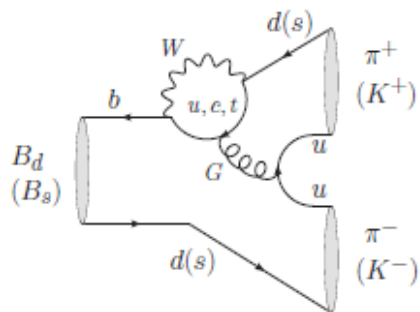


Colour allowed tree

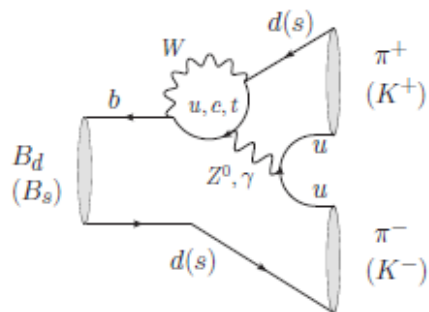


Exchange

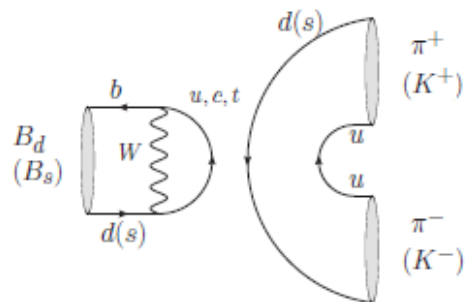
Penguin (pen) :



QCD penguin



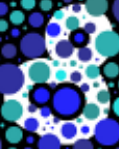
Electroweak penguin



Penguin annihilation

... and challenging to **theoretically** interpret

“Strategies” to Hunt for New Physics with Strange Beauty Mesons

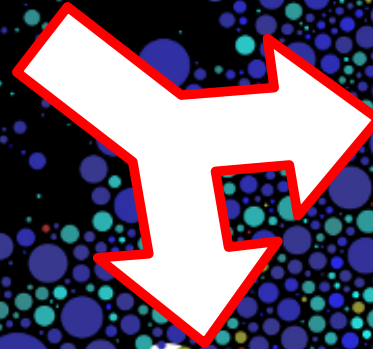
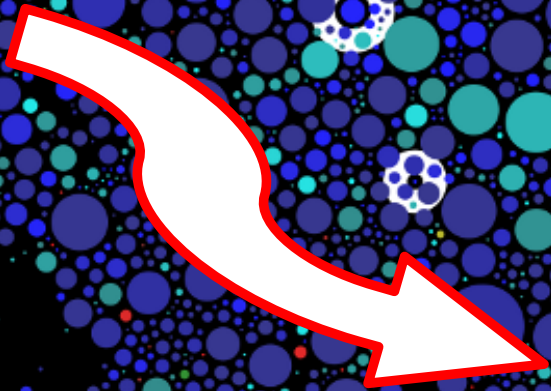


Using quark flavour symmetries



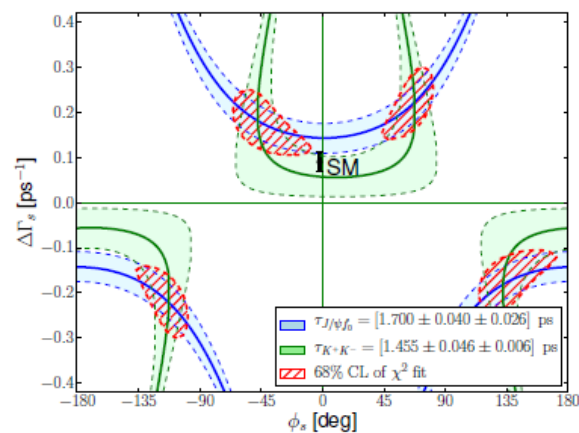
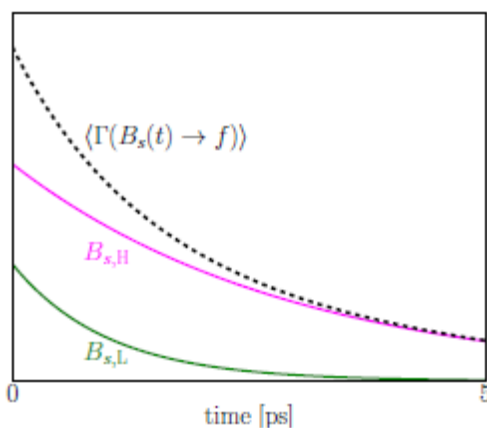
Approximate symmetry lets us
puzzle together various observations

$$B_s \rightarrow K^+ K^- \leftrightarrow B_d \rightarrow \pi^+ \pi^-$$
$$B_s \rightarrow J/\psi (ss) \leftrightarrow B_d \rightarrow J/\psi (dd)$$



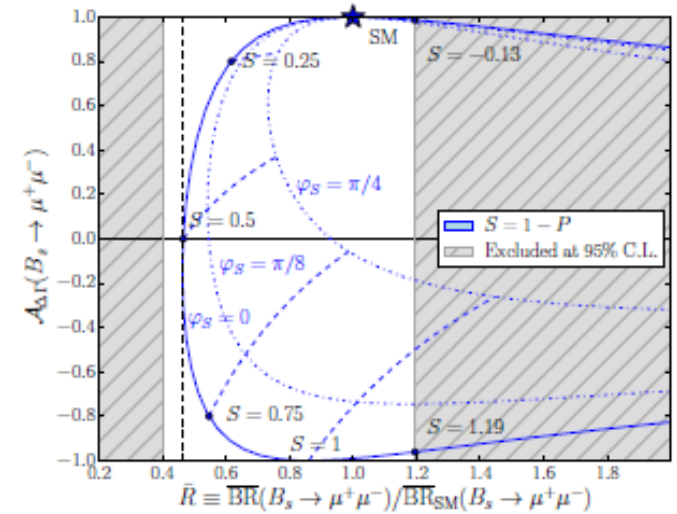
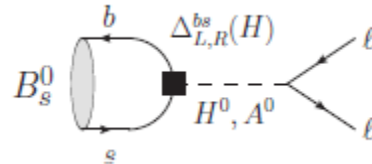
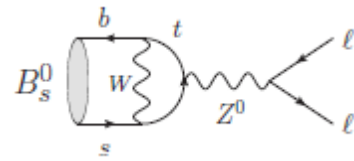
Using effective lifetimes

$$\tau_{\text{eff}} \equiv \frac{\int_0^{\infty} t \langle \Gamma_f \rangle dt}{\int_0^{\infty} \langle \Gamma_f \rangle dt} = \frac{\tau_{B_s}}{1 - y_s^2} \left(\frac{1 + 2 \mathcal{A}_{\Delta\Gamma}^f y_s + y_s^2}{1 + \mathcal{A}_{\Delta\Gamma}^f y_s} \right)$$



Using a rare decay

$B_s \rightarrow \mu^+ \mu^-$ occurs once in 300 million



Considered mass-eigenstate rate asymmetry:

$$\begin{aligned}
 & |\langle \ell_\lambda^+ \ell_\lambda^- | \mathcal{H}_{\text{eff}} | B_{s,L} \rangle|^2 \\
 &= 2|N|^2 \{ |P|^2 \sin^2 (\varphi_P - \phi_s^{\text{NP}}/2) + |S|^2 \cos^2 (\varphi_S - \phi_s^{\text{NP}}/2) \}
 \end{aligned}$$

