



NETZWERK
TEILCHENWELT



DPG-Frühjahrstagung Gießen 2024 HK 43.6

An Innovative Introduction into Hadron Physics: The LHCb Quark-Puzzle

Lukas Julian Exner¹, Sebastian Neubert¹, Klaas Padeken¹

¹ HISKP, University of Bonn

13th of March



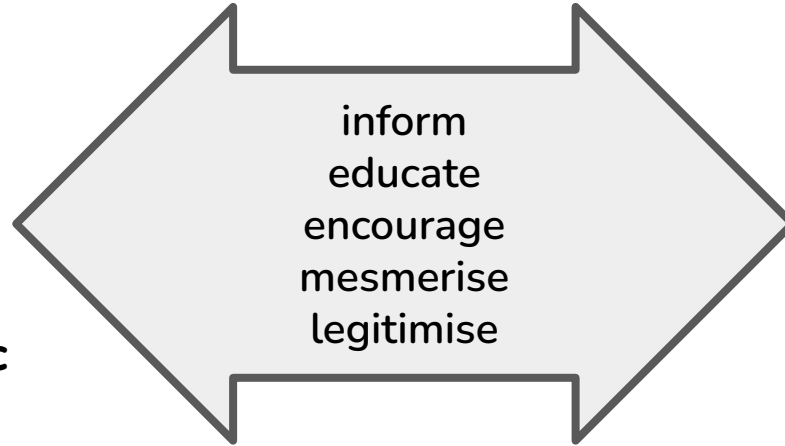


Society

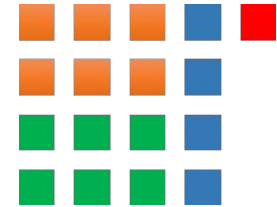


Pupil
Interested
General public
Students

Outreach



Science



Particle
and
Hadron physics

Methods



Concept

3d printable puzzle

Visualisation

Education

Self-initiated

playful discovery of properties and symmetries of
quarks, hadrons and the strong force

**teacher-centered
instruction**

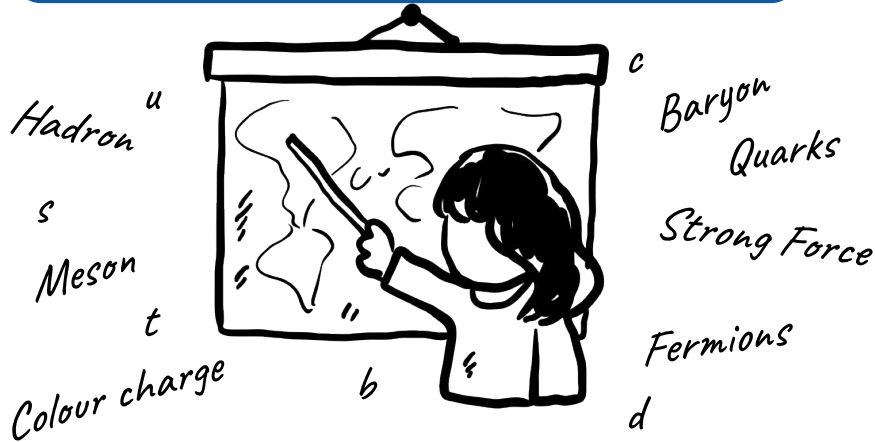
vs.

inquiry learning approach

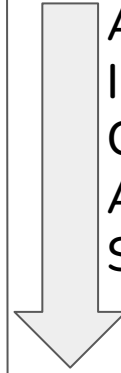
teacher-centered
instruction

vs.

inquiry learning approach

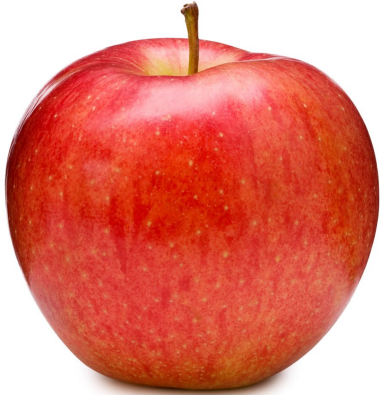


Passive listening
Leds to overload and boredom



Active (independent) work
Inductive thinking
Constructing a mental model & meaning
Autonomy
Self-efficacy

Interest & memorisation



“divide a symmetrical body into three symmetrical parts, so that the combination two of these parts are symmetrical again”

Physics

- six quark flavours
- six quark anti-flavours
- three colours
- three anti-colours
- colour neutral mesons
- colour neutral baryons and anti-baryons
- top-quarks do not form hadrons

Formalities

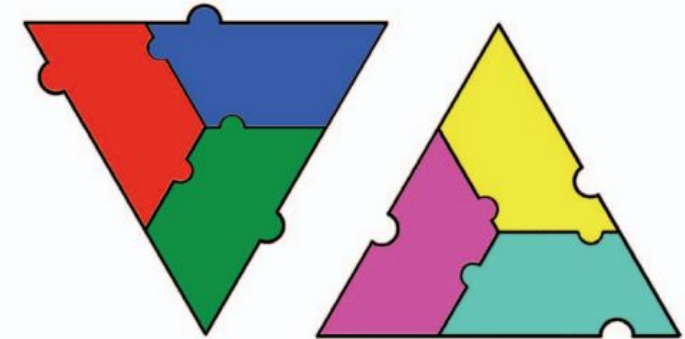
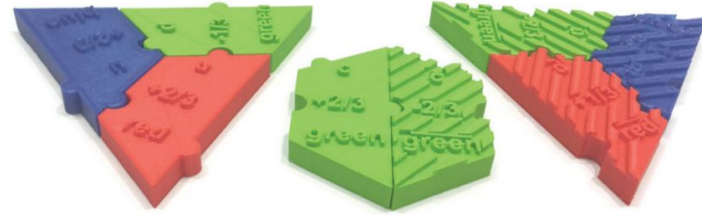
- vivid visualisation, best: 3-dimensional
- symmetrical and basic shape
- closed

Currently available
at CERN Science
Gateway

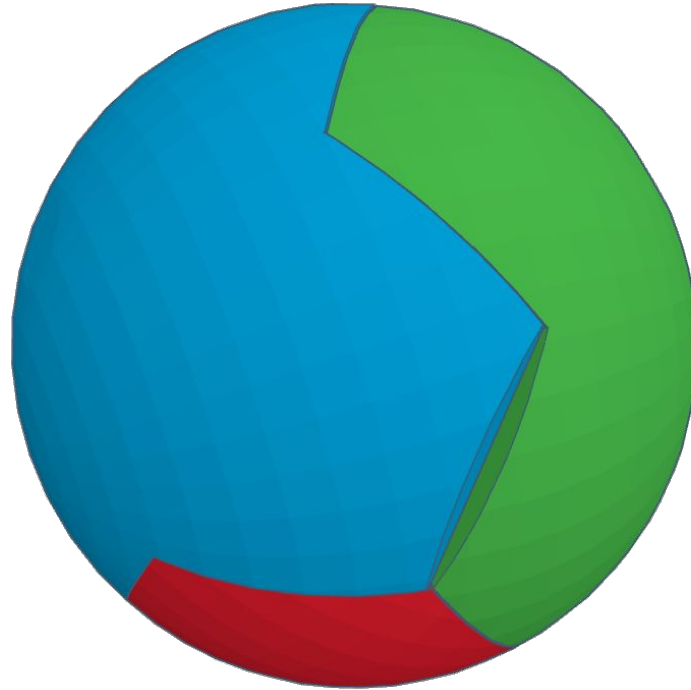
Gettrust., Phys. Teach 48 (2010)



McGinness et al., Phys. Teach 57 (2019)

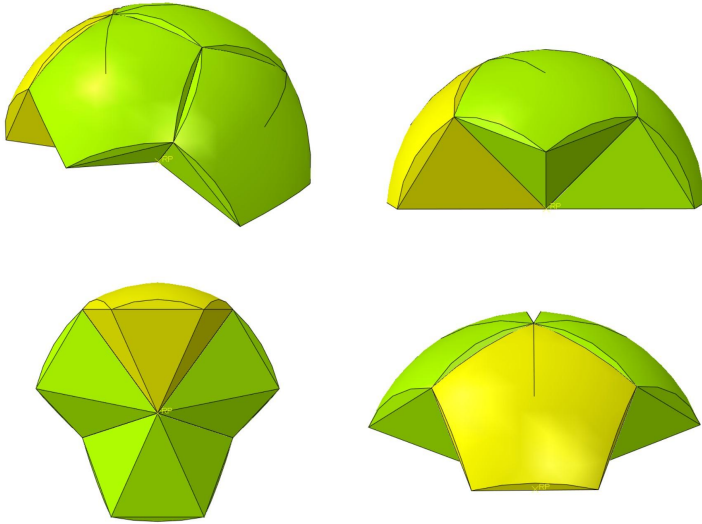


Solution: Dodecahedron

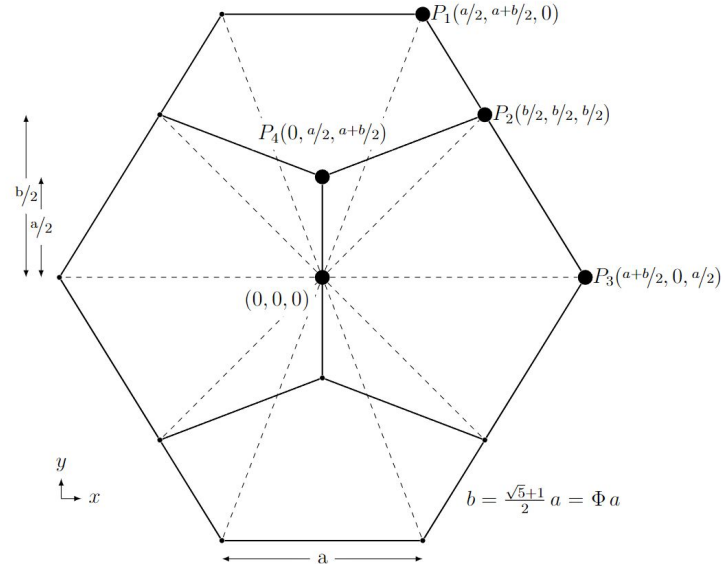


Solution: Dodecahedron as illustration of SU(3)

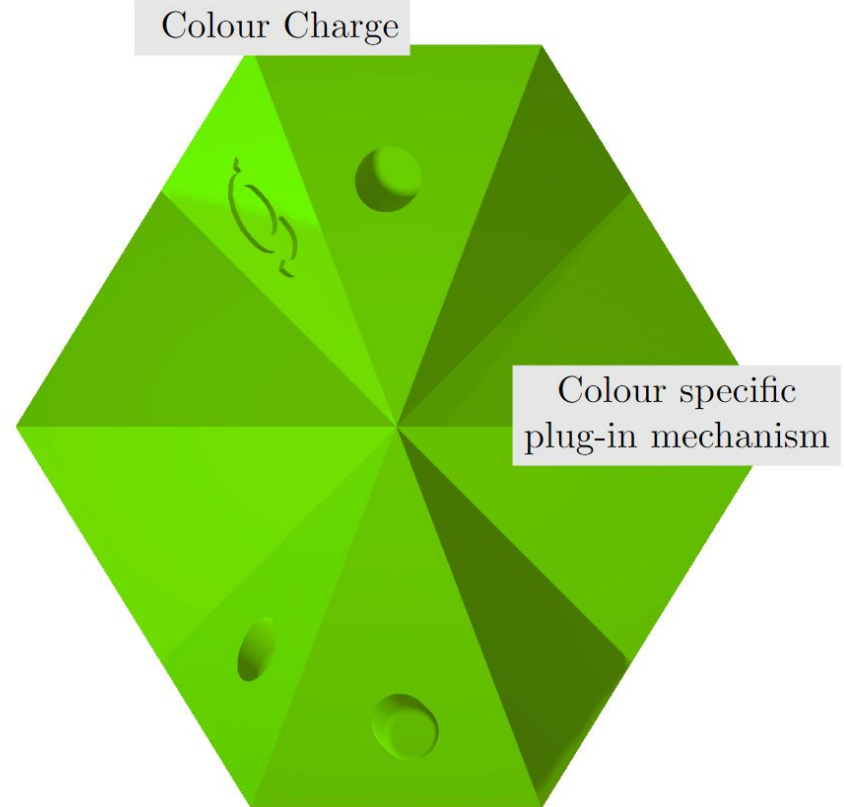
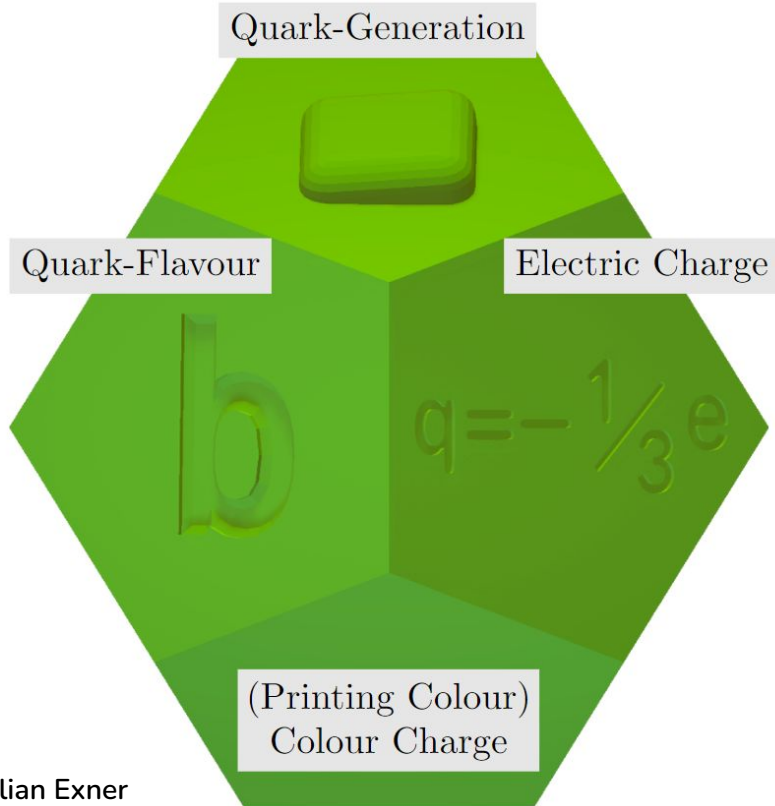
Quark



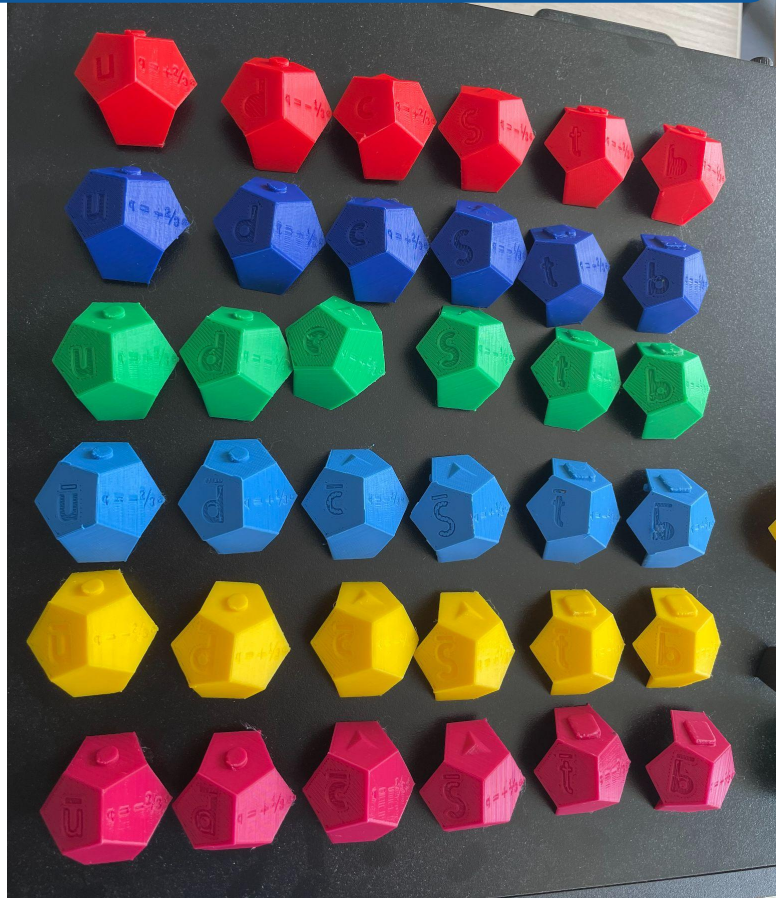
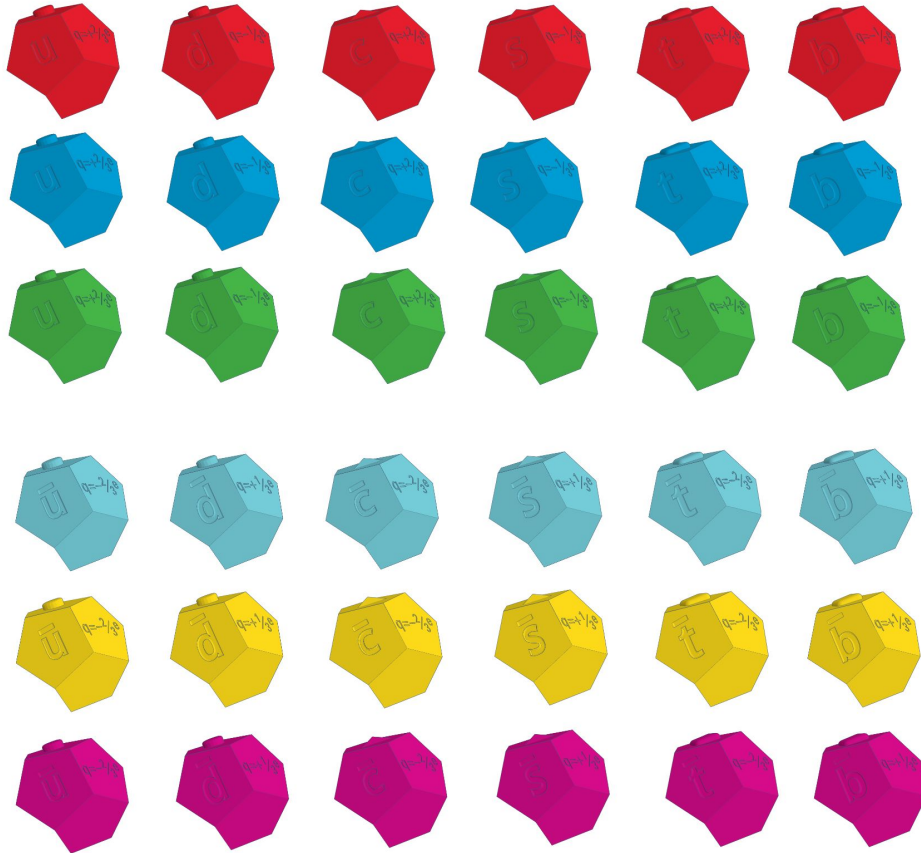
Baryon



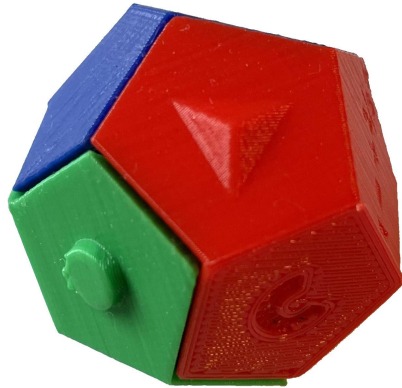
Much easier to construct



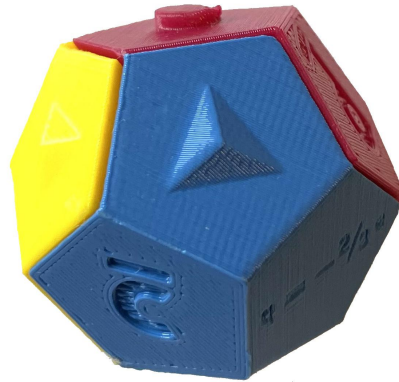
All LHCb Quark Puzzle Pieces



Baryons

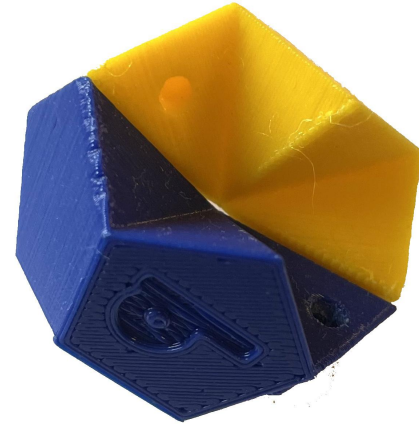


Anti-baryons

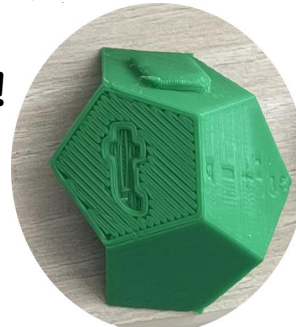


Mesons

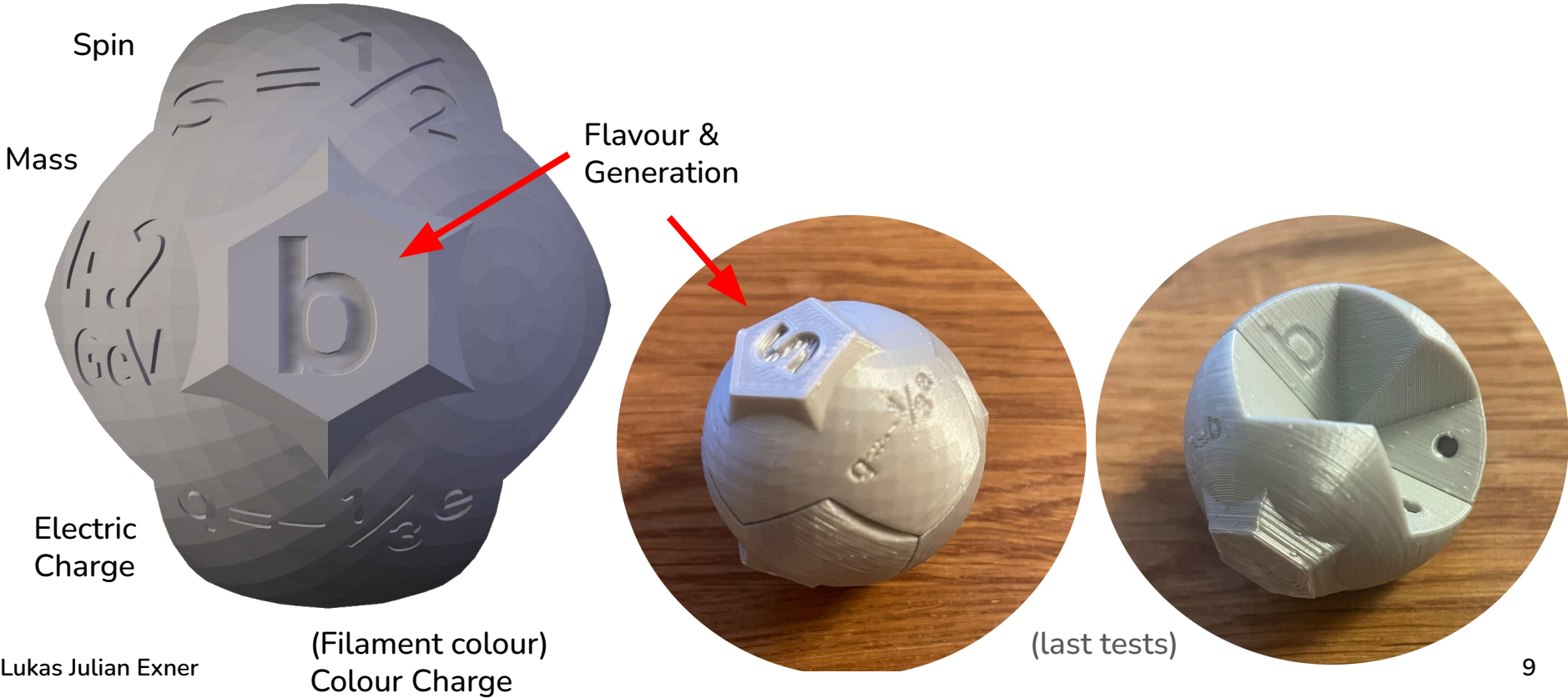
(3 in total)

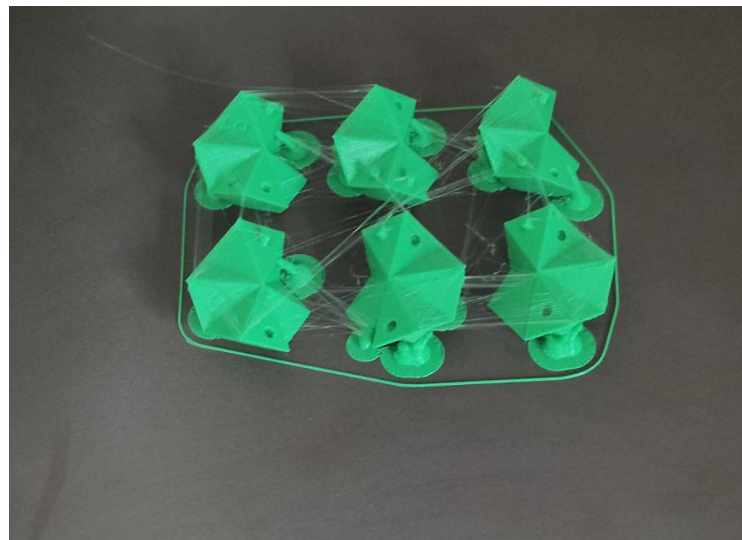


Only colour-neutral hadrons can be built!



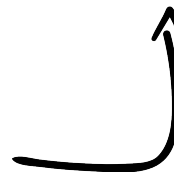
**top-Quarks
have no plugs!**





Printed at FTD

Credits to
Klaas Padeken, Niclas Sommerfeld



University

School

Outreach

Quark-Puzzle part of LHCb Masterclass

little prior knowledge
Do the LHCb Quark Puzzle
Let hypotheses be formulated

Talk about physics
e.g. introduce vocabulary

Build up specialised knowledge

- Decays
- Interactions
- Masses
- Colour
- ...

2.6 Der Vortrag anschließend hat gehalten, die Erkenntnisse im Puzzle zu reflektieren

Als Geburtstagsgeschenk

2.7 Ich will das Puzzle für zu Hause!

für meinen Physiklehrer

~~Puzzle zu reflektieren~~



2.7 Ich will das Puzzle für zu Hause!

~~Puzzle zu reflektieren~~

2.7 Ich will das Puzzle für zu Hause! *eher schulunterricht*

Das möchte ich unbedingt noch loswerden...

Das Puzzle ist sehr cool



Interested?

Print for FREE (under CC BY-ND)

exner@uni-bonn.de

Version 1

github.com/lexner/Quark-Puzzle

thingiverse.com/thing:6150640

NTW: uni-bonn.sciebo.de/s/HlaWb8pqcPxXftJ



thingiverse



sciebo
(NTW-Version)



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Version 1

github.com/lexner/Quark-Puzzle
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NTW: uni-bonn.sciebo.de/s/HlaWb8pqcPxXftJ

Version 2

Coming next weeks

Paper

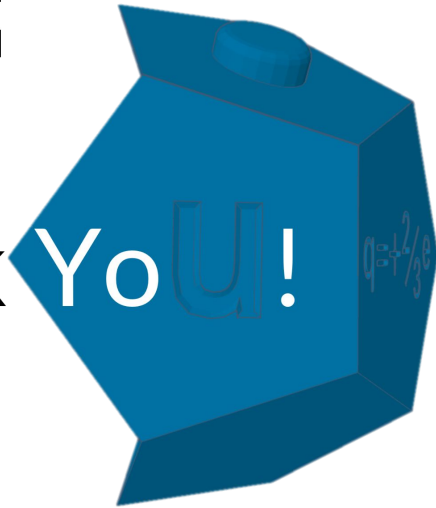
Coming soon

Tetra, penta and
hexaquarks

already plans



V1 NTW
sciebo



Thank You!

V1
thingiverse



Try the LHCb Quark Puzzle now!

- α of V1 is here
- Last tests of V2 are here

Lukas Julian Exner

exner@uni-bonn.de



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References

E. Gettrust, The quark puzzle: A novel approach to visualizing the color symmetries of quarks, *Phys. Teach* 48 (2010) 312.

L. McGinness, S. Dührkoop, J. Woithe, and A. Jansky, 3D Printable Quark Puzzle: A Model to Build Your Own Particle Systems, *The Physics Teacher* 57 (2019) 526.