

Standard Model of Physics - on Rubik's 4x4 Cube

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PARTICLE GAMES – STUDENT IDEA

2011: Four basic particle card games

by Cs. Török, Judit Csörgő, T. Cs., BerzeTÖK Science Club in Gyöngyös, Hungary

1. ANTI
2. Cosmic Showers
3. Let's Detect!
4. Quark Matter Card Game

2012: talks, demonstrations and presentations

5. Memory of Quark Matter [arXiv:1303.2798](https://arxiv.org/abs/1303.2798)
6. Find Your Own Higgs Boson [arXiv:1303.2732](https://arxiv.org/abs/1303.2732)
7. Particle Poker (Academia Europaea, Bergen)
8. Particle 66, Machiavelli (CERN Open Days)

2013: talks, demonstrations and presentations

9. Quark Wars: Summer Camp of Berze Science Club, Vesznek
10. Particle Mahjongg - Mártély, Camp of Science Club Movement

2014: WPCF 2014 conference, KRF, Gyöngyös, Hungary

11. Quark Matter on Rubik's 3x3 Cube [arXiv:1702.06217 \[physics.pop-ph\]](https://arxiv.org/abs/1702.06217)
12. Particle Hits! – CERN @ Wigner Open Days, Budapest

2016: Low-x 2016, KRF, Gyöngyös, Hungary

13. LHC Experiments Rubik's Void, with a Black Hole [\(talk.pdf\)](#)

2023: ISMD 2023, MATE KRC, Gyöngyös, Hungary

- 13+1. Standard Model of Elementary Particles on Rubik's 4x4 Cube
- +2. Standard Model Card Game: Find your own Odderon!

ELEMENTARY PARTICLES

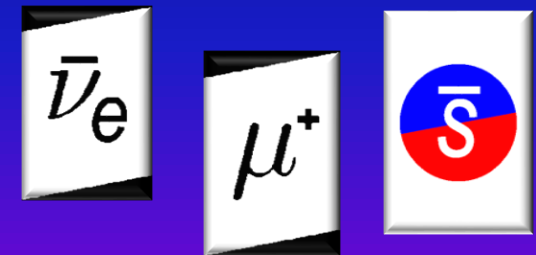
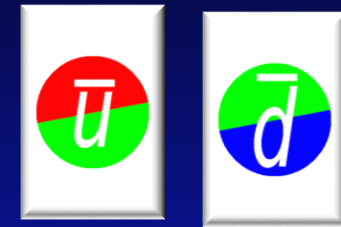
Three generations of matter (fermions)

	I	II	III		
mass →	2.4 MeV/c ²	1.27 GeV/c ²	171.2 GeV/c ²	0	? GeV/c ²
charge →	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0	0
spin →	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	0
name →	u up	c charm	t top	γ photon	H Higgs boson
	4.8 MeV/c ²	104 MeV/c ²	4.2 GeV/c ²	0	
	$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	0	
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	
Quarks	d down	s strange	b bottom	g gluon	
	<2.2 eV/c ²	<0.17 MeV/c ²	<15.5 MeV/c ²	91.2 GeV/c ²	
	0	0	0	0	
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	Z⁰ Z boson	
	0.511 MeV/c ²	105.7 MeV/c ²	1.777 GeV/c ²	80.4 GeV/c ²	
	-1	-1	-1	± 1	
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	
Leptons	e electron	μ muon	τ tau	W[±] W boson	Gauge bosons

ELEMENTARY PARTICLES - PLAYFULLY

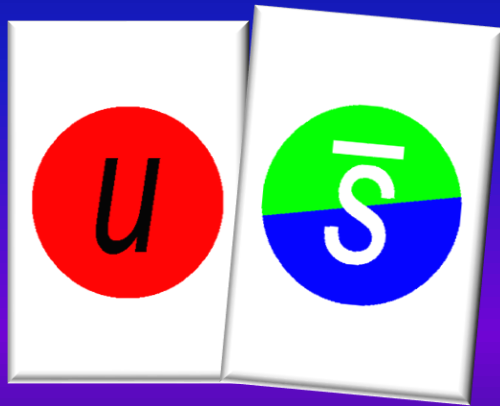
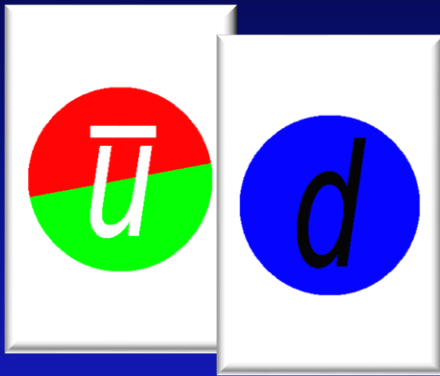
Three generations of matter (fermions)

	I	II	III		
mass →		1.27 GeV/c ²	171.2 GeV/c ²	0	? GeV/c ²
charge →		² / ₃	² / ₃	0	0
spin →		¹ / ₂	¹ / ₂	1	0
name →	u	c charm	t top	γ photon	H Higgs boson
	d	s	4.2 GeV/c ² ⁻² / ₃ b bottom	0 0 1 g gluon	
Quarks					
	ν_e	ν_μ	<15.5 MeV/c ² 0 ¹ / ₂ ν_τ tau neutrino	0 0 1 Z⁰ Z boson	
	e⁻	μ⁻	1.777 GeV/c ² -1 ¹ / ₂ τ tau	±1 1 W[±] W boson	
Leptons					Gauge bosons

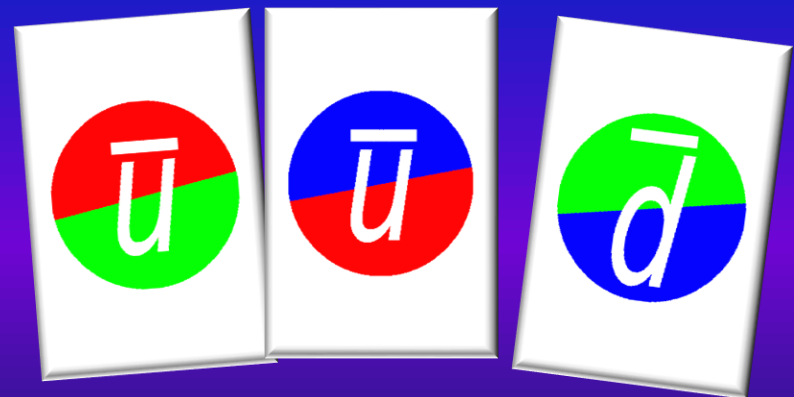
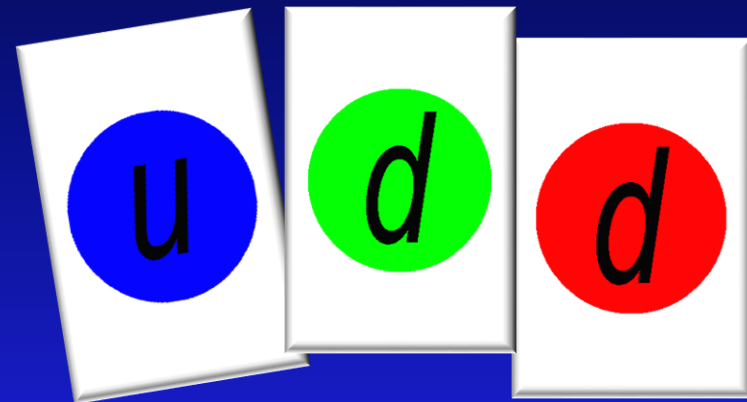


SU(3) COLOR AND OPTICAL COLOR

Mesons

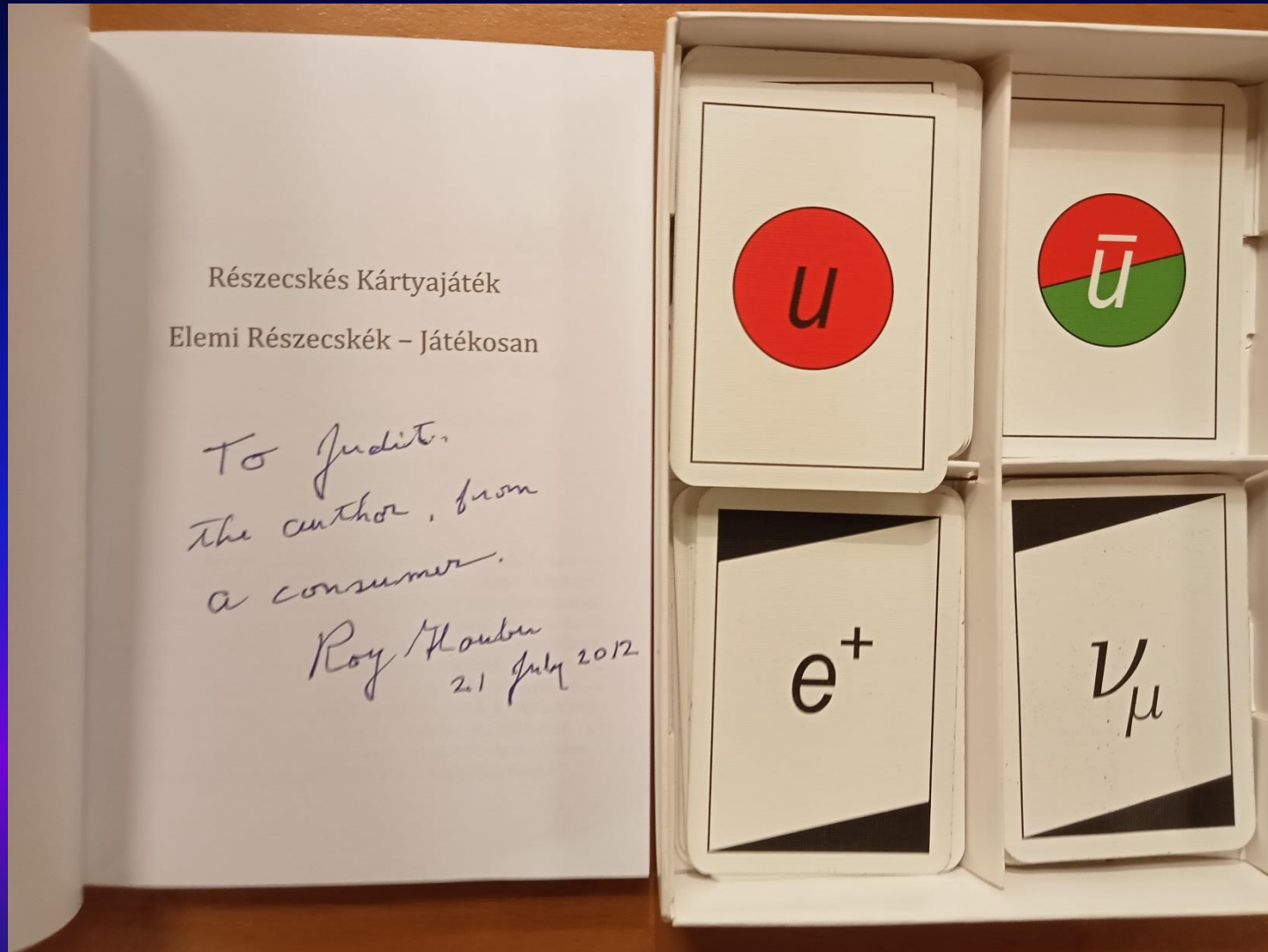


Baryons



Quark Matter Card Games

Dedication to the author, by Roy J. Glauber (Harvard)
Nobel Laurate in physics (2005)



QUARK MATTER – ON RUBIK'S CUBE



Perfect Fluid of Quarks – on Rubik's Cube

locally, color is deconfined

globally, color neutral

Red opposite to anti-red (green/blue)

Green opposite to anti-green (blue/red)

Blue opposite to anti-blue (red/green)

quarks opposite to anti-quarks

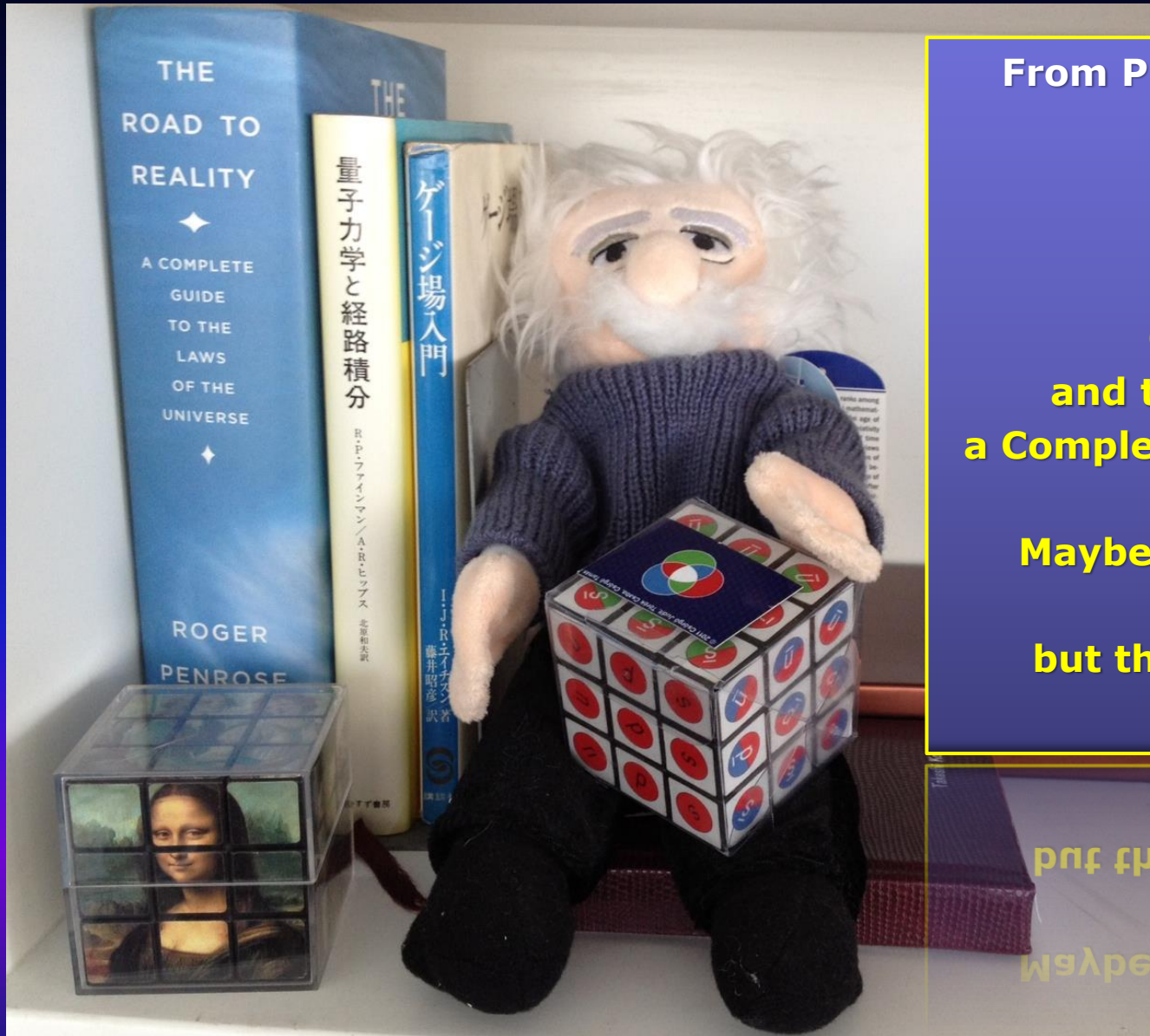
conservation laws

rotates and „expands”

large degree of internal disorder (entropy)

small shear – illustration of perfect fluidity

QUARK MATTER – WITH A SMILE

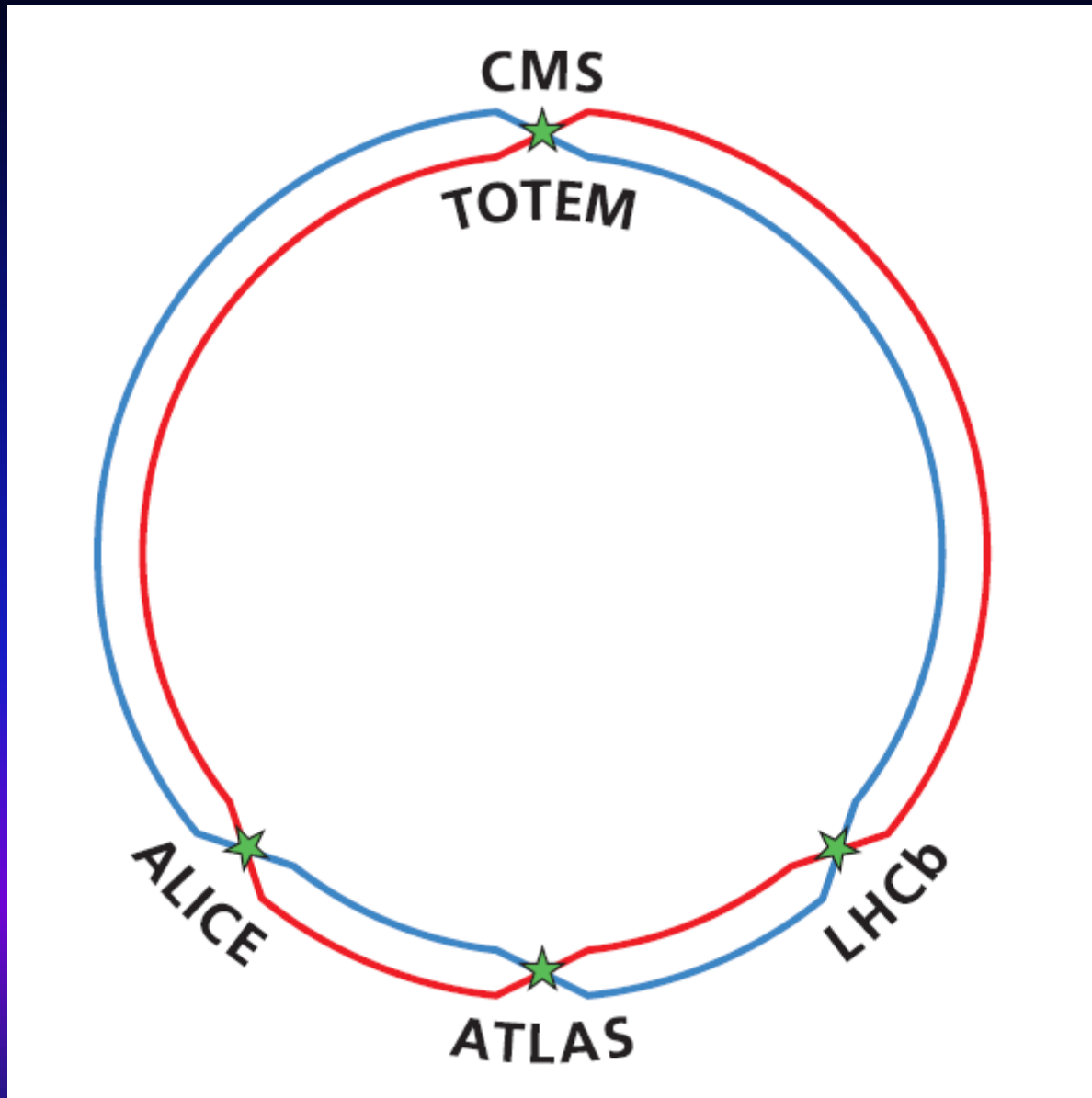


From Professor T. Kodama
(Brazil)
connecting
Albert Einstein,
Mona Lisa Cube,
Quark Matter Cube,
and the Road to Reality:
a Complete Guide to Nature.

Maybe particle games are
not so complete,
but their way is certainly
so interesting.

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Maybe particle games are

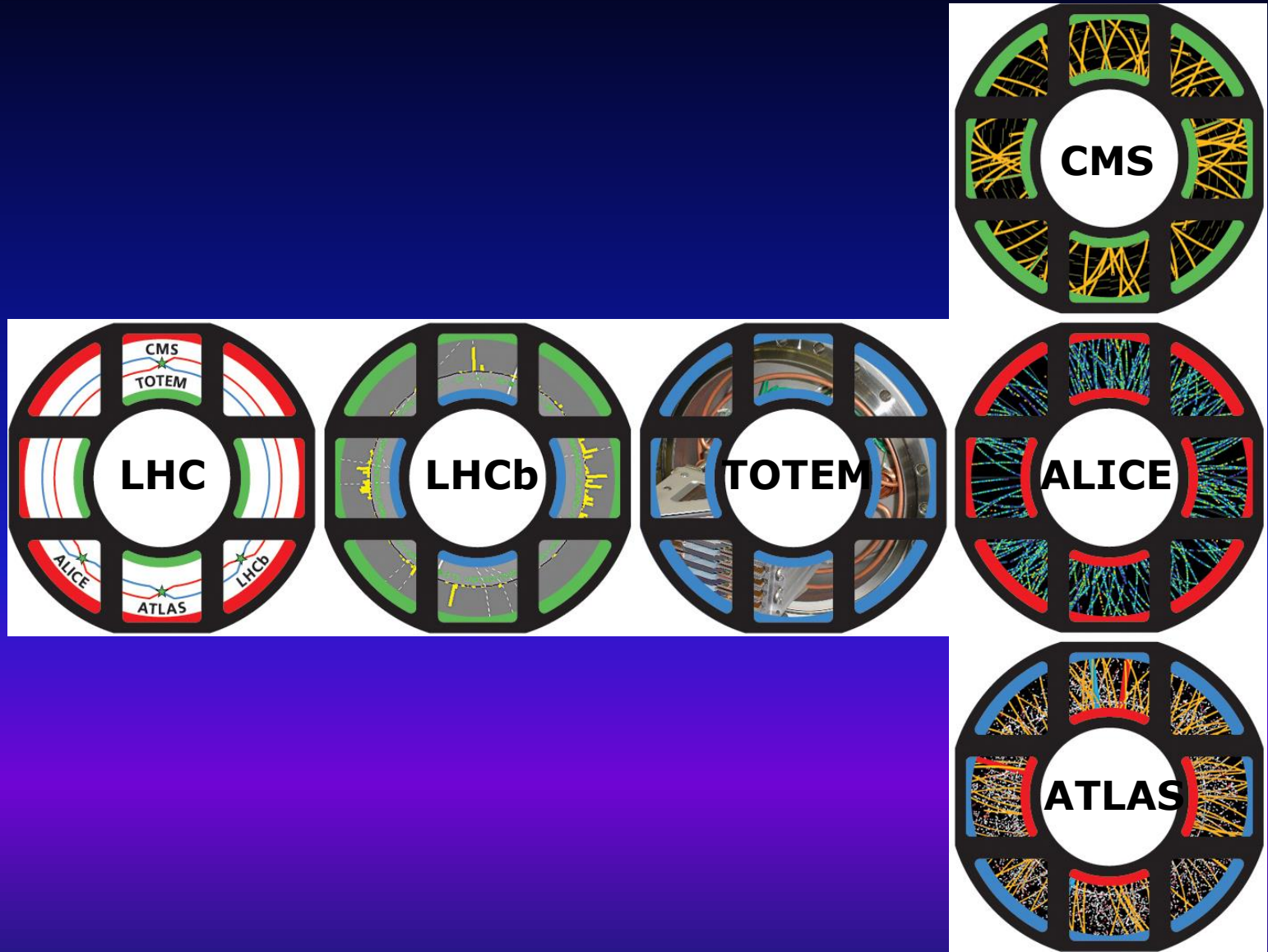
LHC and its 5 major experiments



Rubik's Void Cube



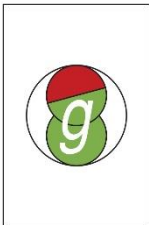
LHC Experiments on Rubik's Void



Standard Model Card Games

Find your own Odderon! – see Georgina's student talk

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name →	u up	c charm	t top	γ photon	H Higgs boson
					
Quarks	4.8 MeV/c ² $-\frac{1}{3}$ d down	104 MeV/c ² $-\frac{1}{3}$ s strange	4.2 GeV/c ² $-\frac{1}{3}$ b bottom		
	<2.2 eV/c ² 0 $\frac{1}{2}$ ν_e electron neutrino	<0.17 MeV/c ² 0 $\frac{1}{2}$ ν_μ muon neutrino	<15.5 MeV/c ² 0 $\frac{1}{2}$ ν_τ tau neutrino	91.2 GeV/c ² 0 Z⁰ Z boson	
Leptons	0.511 MeV/c ² -1 $\frac{1}{2}$ e electron	105.7 MeV/c ² -1 $\frac{1}{2}$ μ muon	1.777 GeV/c ² -1 $\frac{1}{2}$ τ tau	80.4 GeV/c ² ± 1 1 W[±] W boson	Gauge bosons

Standard Model of Elementary Particles

Glucos also represented
Change color
Change anti-color

Fits nicely to Rubik's 4x4x4 cube
Six sides:
3 colors + 3 anti-colors

Particles
Opposite side:
Anti-particles

What about the Higgs boson?

Bonus extra!

Standard Model on Rubik's 4x4

Presented to the participants of ISMD 2023

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Higgs: attached as key-holder
Need more space for gluons ...

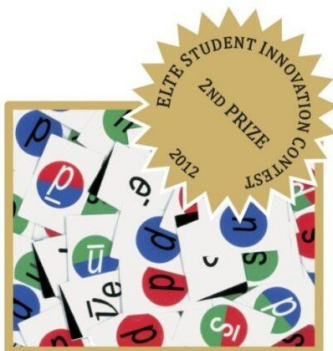
Thank you for your attention!



<https://shop.rubik.hu/en/>

QUARK MATTER CARD GAME

FIND YOUR OWN HIGGS BOSON



J. CSÖRGŐ, CS. TÖRÖK AND T. CSÖRGŐ

Questions?

<https://getyourhiggs.com/>

RÉSZECSKÉS KÁRTYAJÁTÉK

ELEMI RÉSZECSKÉK – JÁTÉKOSAN
2. KIADÁS, KÁRTYA MELLÉKLETTEL



CSÖRGŐ JUDIT
TÖRÖK CSABA
CSÖRGŐ TAMÁS



Legal info:

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The pictures layed out on the faces of the Rubik Void 3x3 cube are CERN material.

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CERN experiments on Rubik's Void with a Black Hole:

© T. Csörgő, presented at Low-x 2016, Gyöngyös, on June 10, 2015.

Standard Model on Rubik's 4x4x4 cube:

© T. Csörgő, presented at ISMD 2023 in Tokaj, Hungary, on August 26, 2023.