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Physics at the Femtometer Scale

Karin Schönning, Uppsala University

5th Conference of Nordic Network for Diversity in Physics
Copenhagen, Denmark, May 24-25 2023

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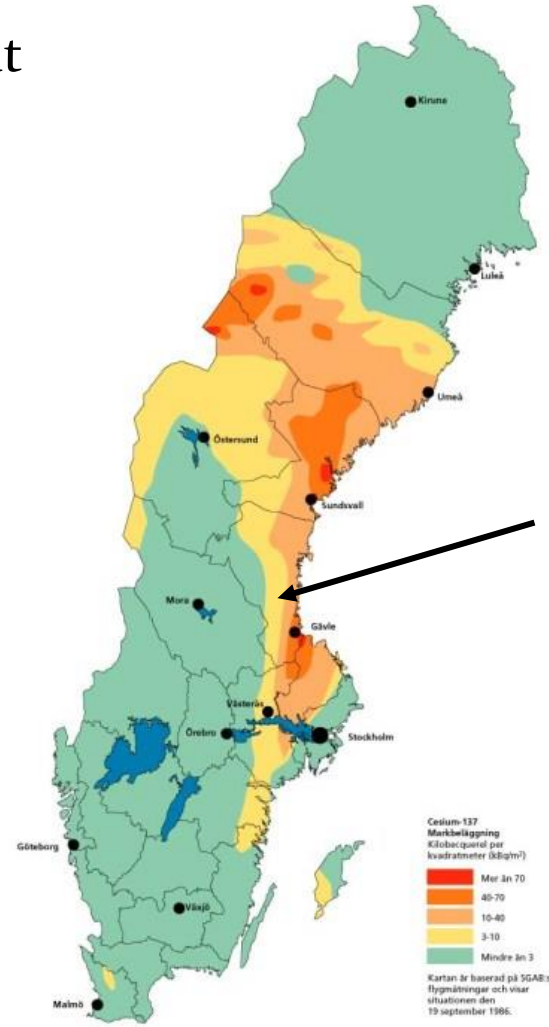
Who am I?

- Professor in experimental hadron physics at Uppsala University since 2020

- Born in Lingbo, Sweden in 1978.



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My career path

- Engineering physics at Uppsala University
- Erasmus studies at ETH Zürich
- Summer student and master project at CERN
- PhD in Uppsala (WASA@CELSIUS)
- Research fellow at CERN (COMPASS)
- Back in Uppsala since 2012
  - BESIII and PANDA since 2012
  - Belle II since 2022

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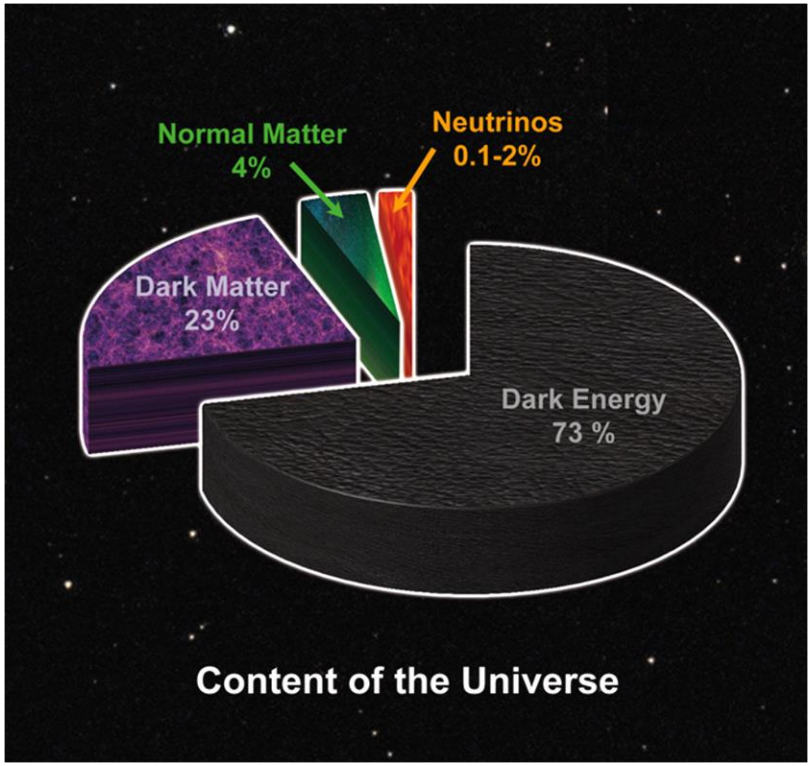
The Universe



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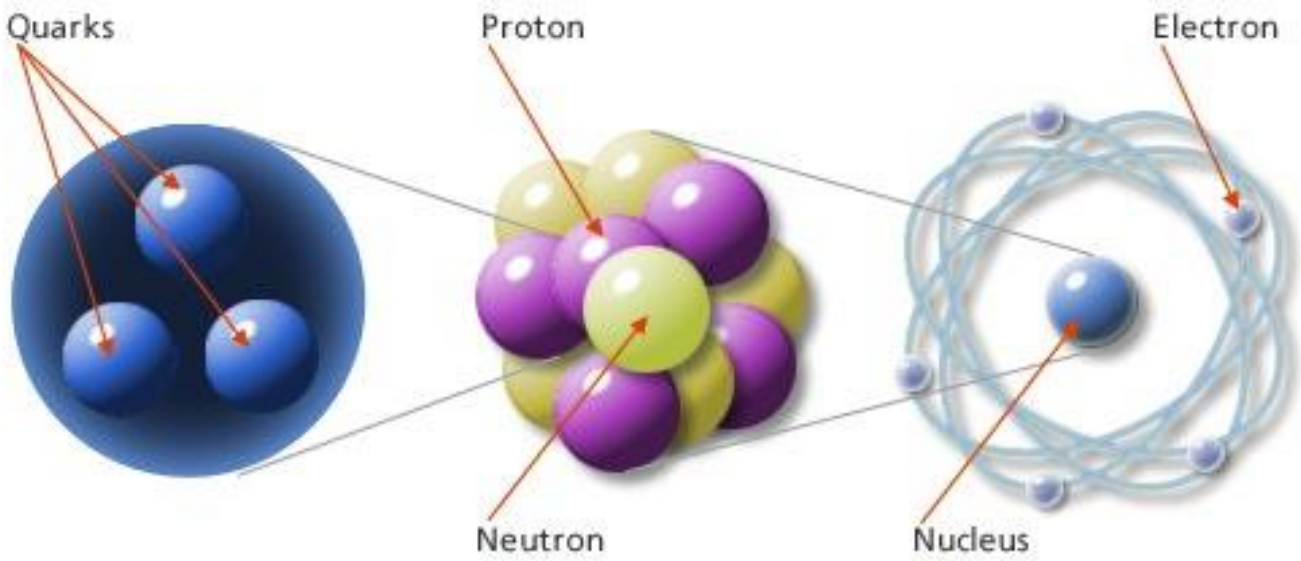
The Visible Matter



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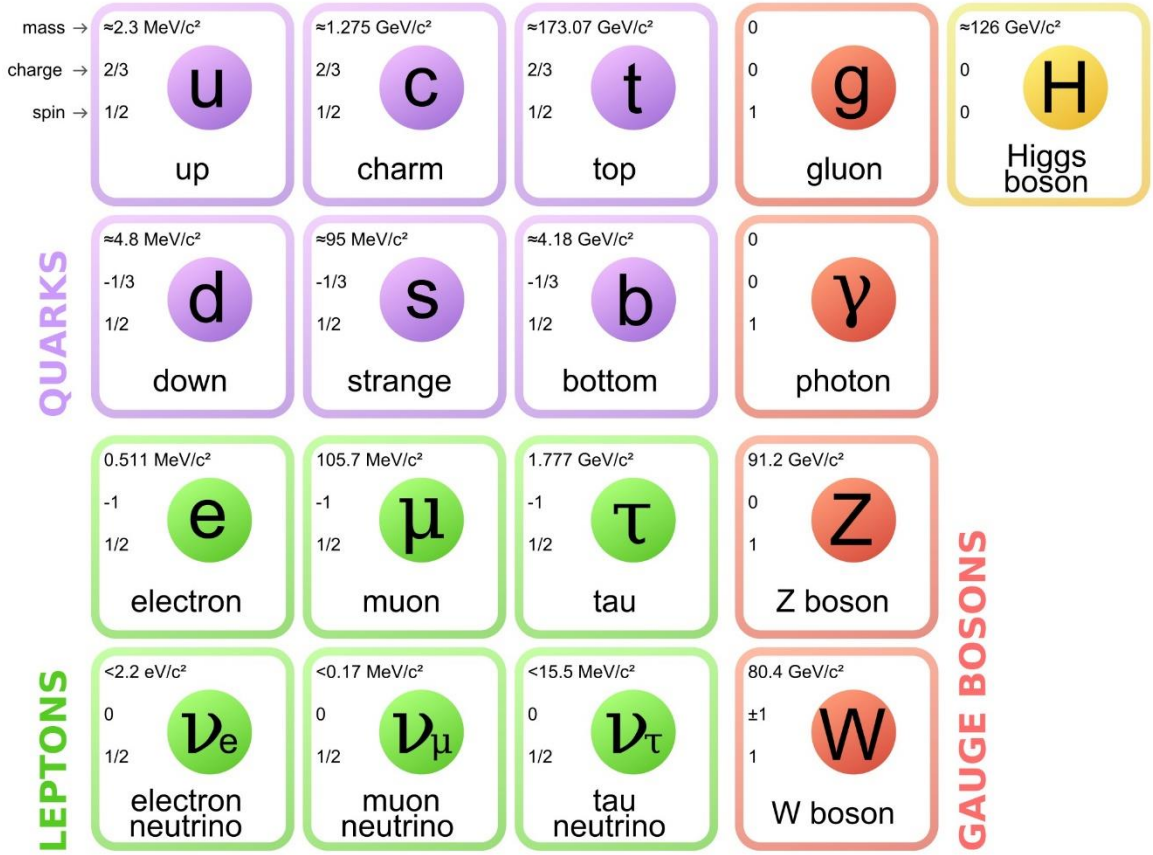
The Standard Model



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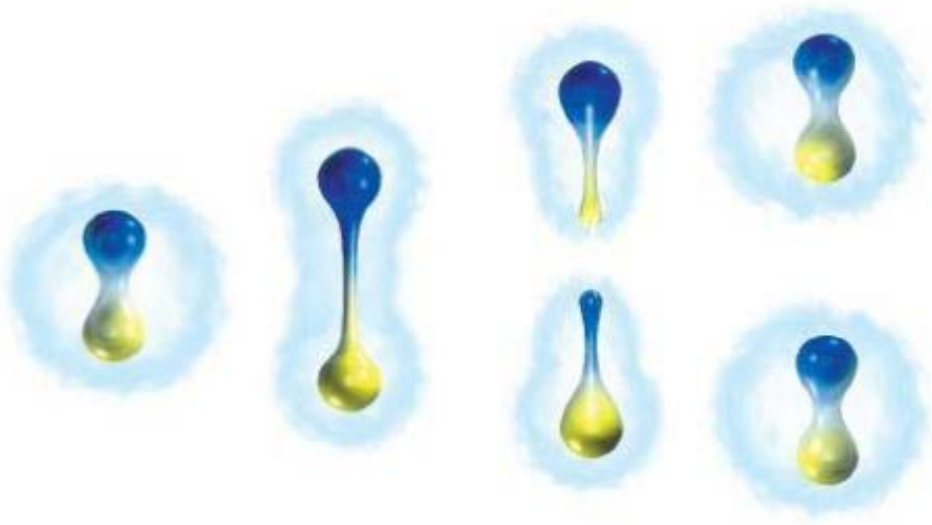
The Strong Interaction

- Acts between colour charged quarks and gluons
- Confines quarks into hadrons
- Generates ~99% of the visible mass of the Universe



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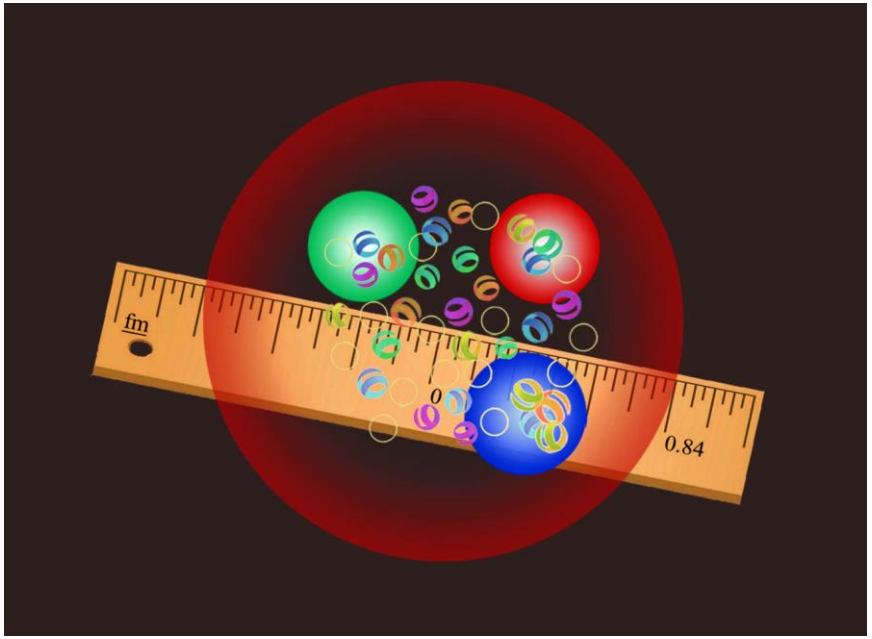
Proton Radius Puzzle

Strong interaction dynamics manifest in *e.g.*

- Charge distributions
- Charge radius

Proton radius:

Very rapidly progressing field!



Picture cred. Y-H Lin, U. Bonn

Proton Radius Puzzle

Ways to measure proton size:

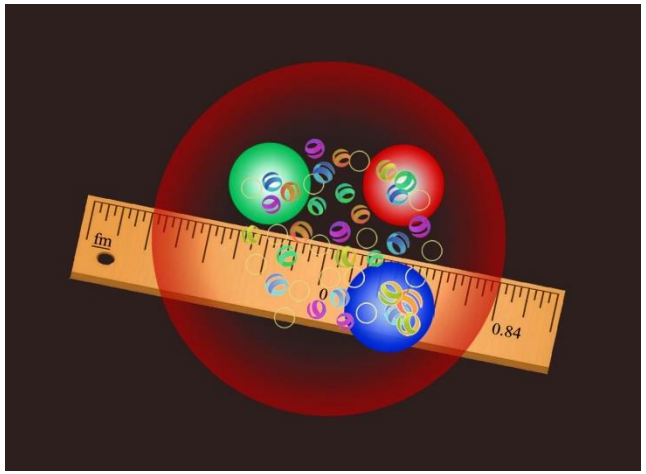
- Electron scattering
- Hydrogen spectroscopy

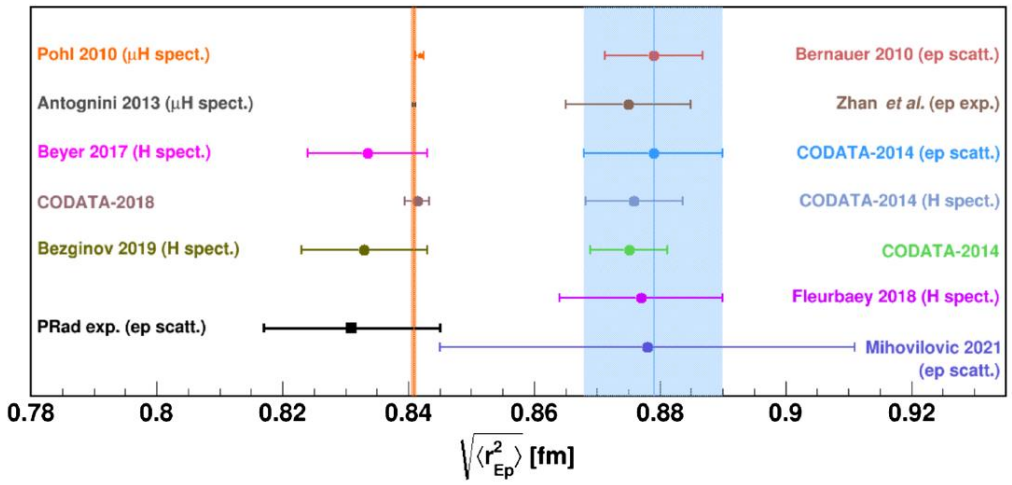
} ~0.88 fm

2010 – 2019:
Unexplained discrepancies
=*Proton radius puzzle**

- Muonic hydrogen spectroscopy

~0.84 fm





*Gao & Vanderhaegen Rev. Mod. Phys. 94, 015002 (2022)
Pictures from
- Y-H Lin, U. Bonn
- Rev. Mod. Phys. 94, 015002 (2022)

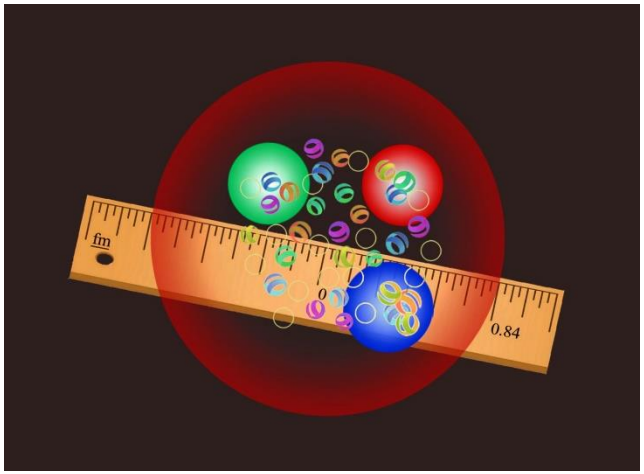
Proton Radius Puzzle

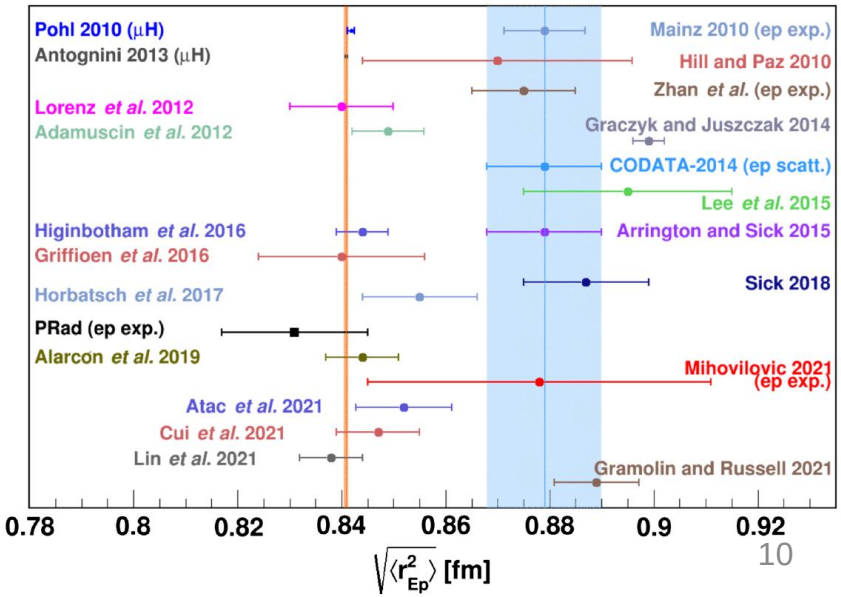
Ways to measure proton size:

- Electron scattering
- Hydrogen spectroscopy

Recently:
Dispersive calculations
Respecting analyticity and
unitarity give consistent results.*

- Muonic hydrogen spectroscopy



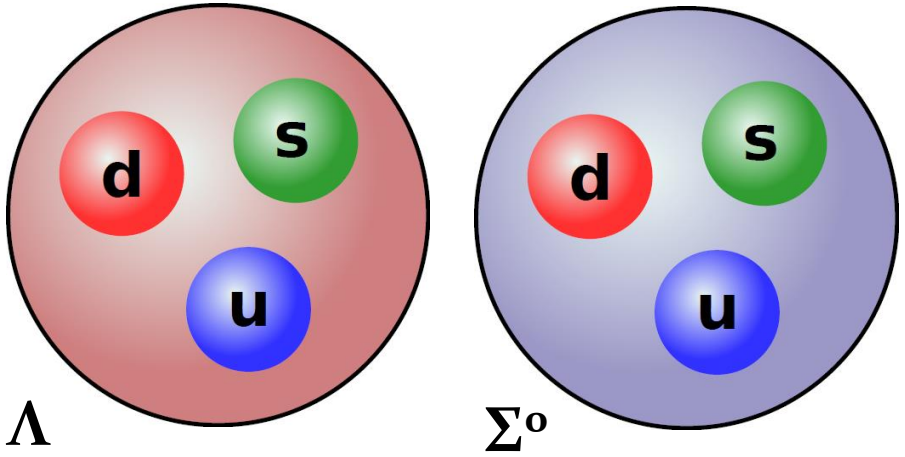


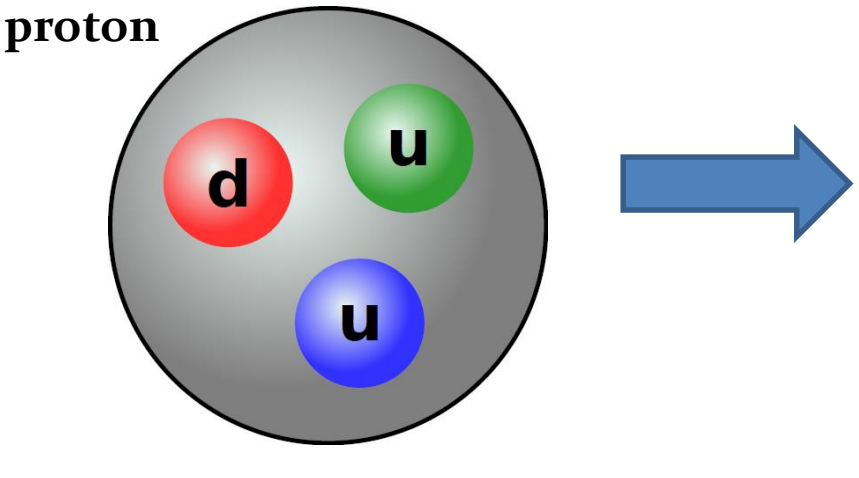
*Lin, Hammer & Meissner, Phys. Rev. Lett. 128, 052002 (2022).

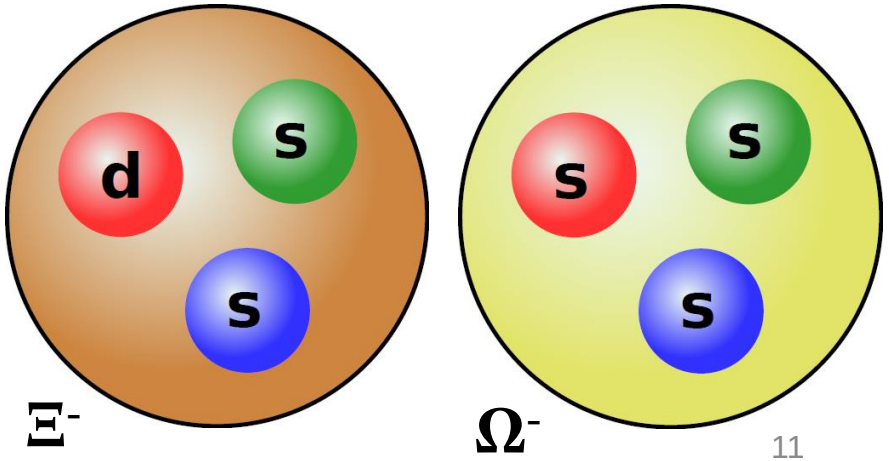
Pictures from
- Y-H Lin, U. Bonn
- Gao & Vanderhaegen, Rev. Mod. Phys. 94, 015002 (2022)

Hyperon Radius?

What happens if we replace one of the light quarks in the proton with one - or many - heavier quark(s)?







Picture cred. Lena Heijkenskjöld

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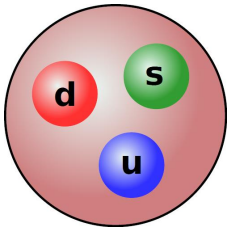
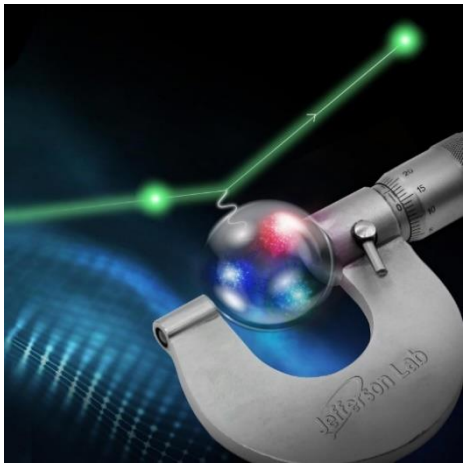
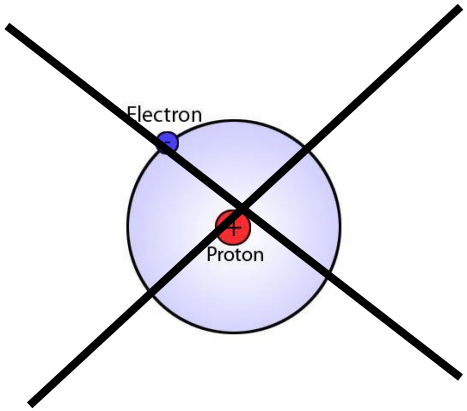
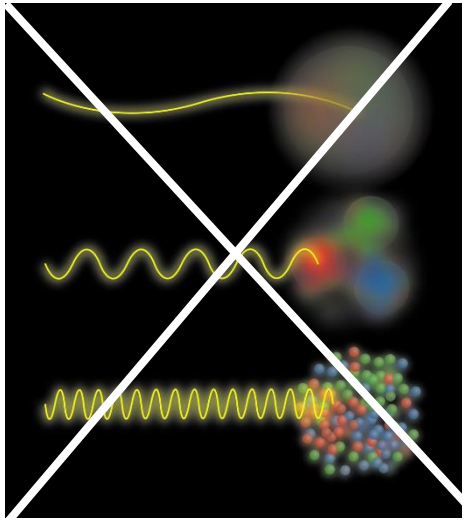
How study hyperon structure?

(decays after ~10^{-10} s)









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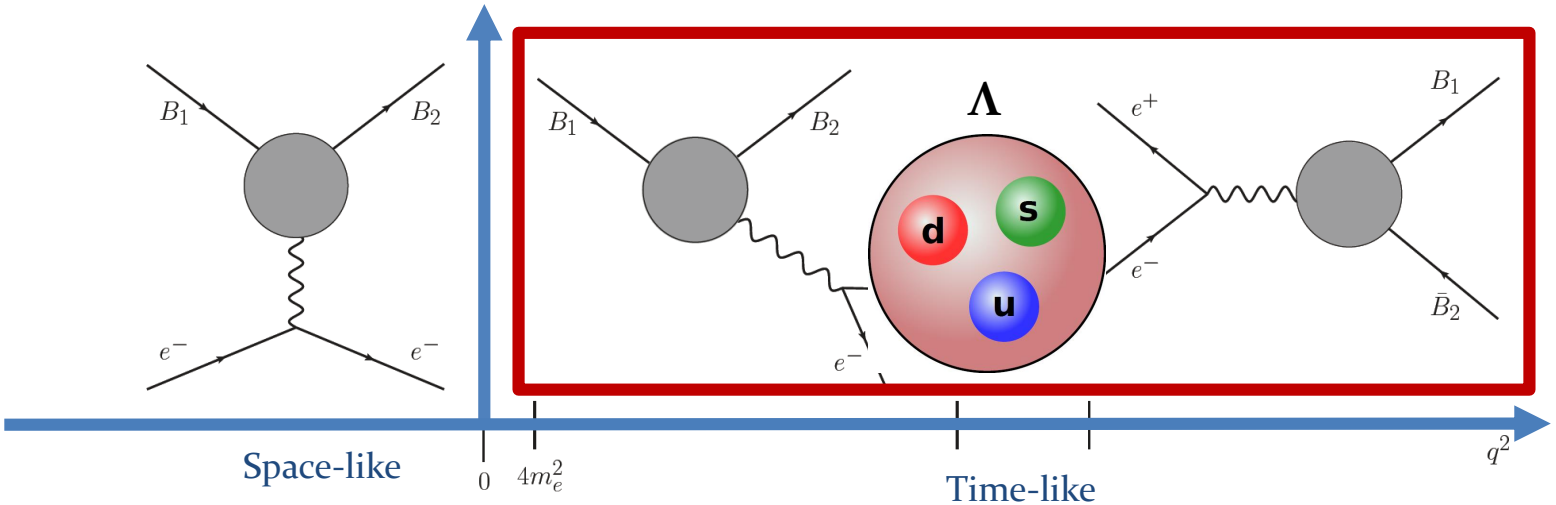
How study hyperon structure?

Space-like

Time-like

How study hyperon structure?



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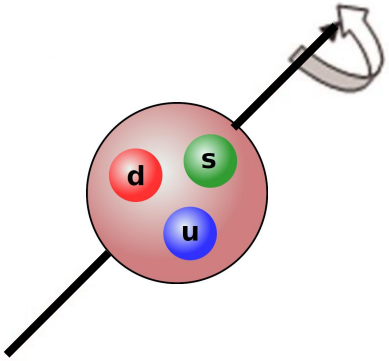
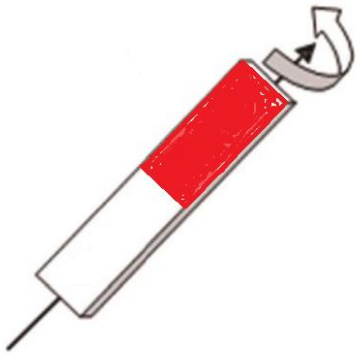
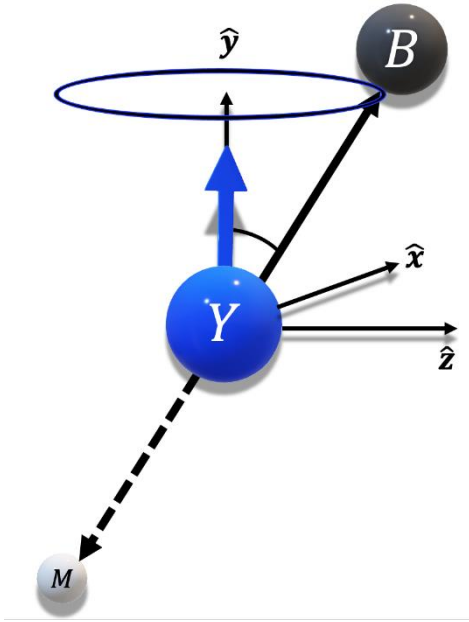
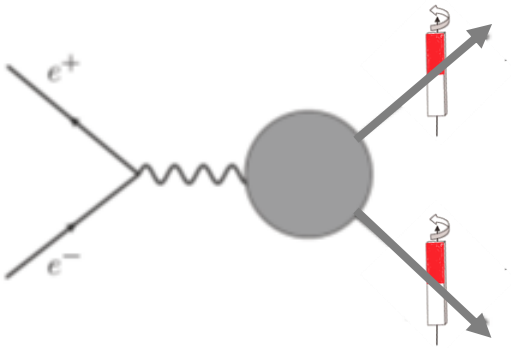
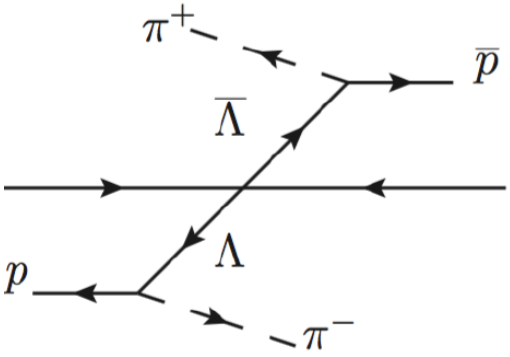
The hyperon's inner magnet











Formalism for $e^+e^- \to \bar{Y}Y, Y \to BM + c.c.$

Production parameters of spin ½ baryons:

- Angular distribution parameter η
- Phase ΔΦ

Decay parameters for 2-body decays: α_1 and α_2.

Unpolarized part Polarized part Spin correlated part

$$W(\xi) = F_0(\xi) + \eta F_5(\xi) - \alpha_1\alpha_2\left(F_1(\xi) + \sqrt{1-\eta^2}\cos(\Delta\Phi)\,F_2(\xi) + \eta F_6(\xi)\right) + \sqrt{1-\eta^2}\sin(\Delta\Phi)(\alpha_1 F_3(\xi) - \alpha_2 F_4(\xi))$$

$$\mathcal{T}_0(\xi) = 1$$

$$\mathcal{T}_1(\xi) = \sin^2\theta \sin\theta_1 \sin\theta_2 \cos\phi_1 \cos\phi_2 + \cos^2\theta \cos\theta_1 \cos\theta_2$$

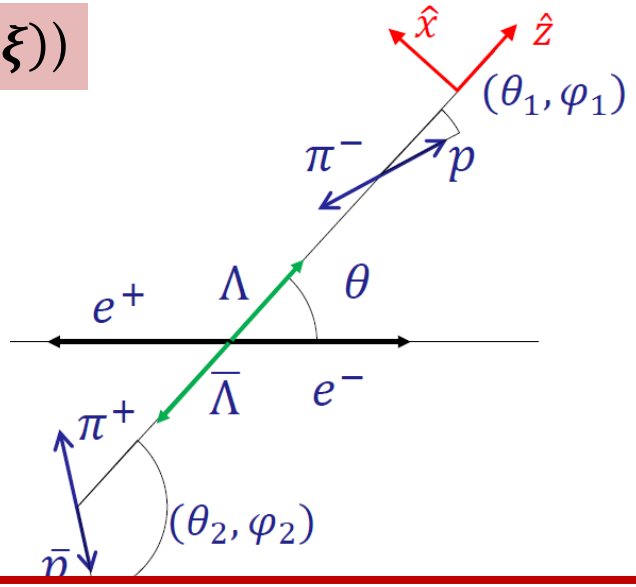
$$\mathcal{T}_2(\xi) = \sin\theta\cos\theta\,(\sin\theta_1 \cos\theta_2 \cos\phi_1 + \cos\theta_1 \sin\theta_2 \cos\phi_2)$$

$$\mathcal{T}_3(\xi) = \sin\theta\cos\theta \sin\theta_1 \sin\phi_1$$

$$\mathcal{T}_4(\xi) = \sin\theta\cos\theta \sin\theta_2 \sin\phi_2$$

$$\mathcal{T}_5(\xi) = \cos^2\theta$$

$$\mathcal{T}_6(\xi) = \cos\theta_1 \cos\theta_2 - \sin^2\theta \sin\theta_1 \sin\theta_2 \sin\phi_1 \sin\phi_2$$



*Fäldt & Kupsc, PLB 772 (2017) 16.

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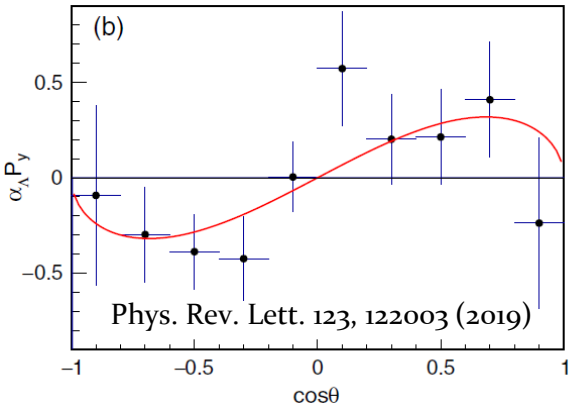
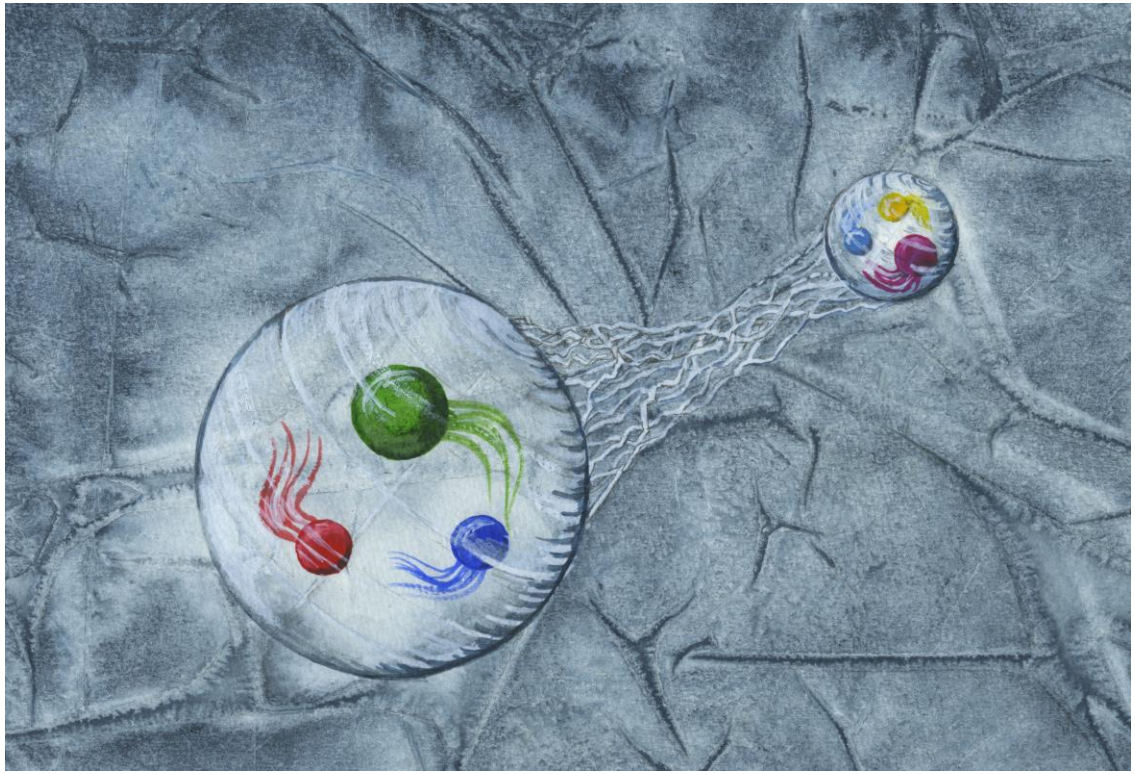
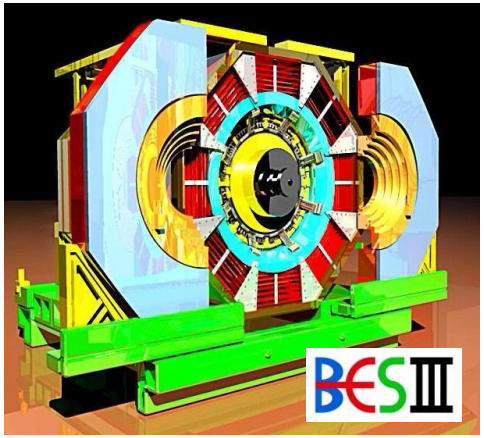
First ”snapshot” of a hyperon in the making!





Copyright: Annika Rockström, Bilder & Berättelser



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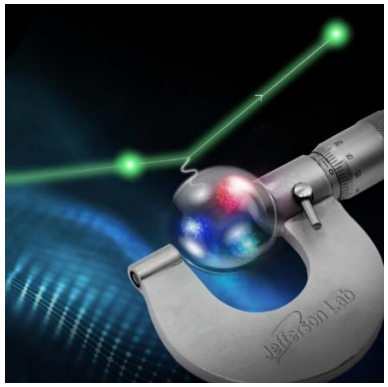
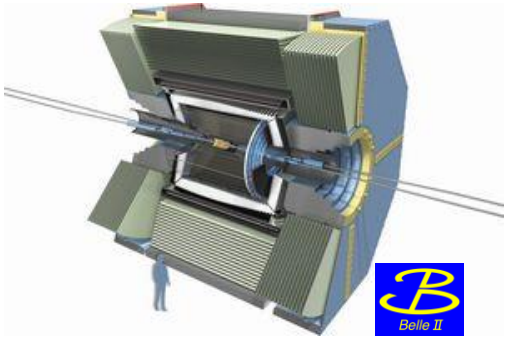
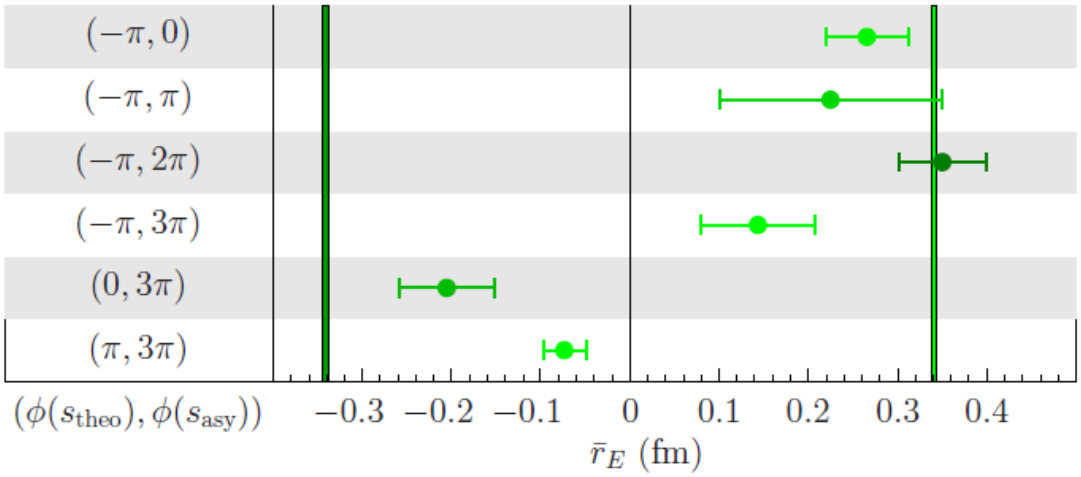


”Snapshot” → Information about radius

”Movie sequence” → Determination of radius



Mangoni *et al.*, Phys. Rev. D 104, 116016 (2021)



My advice to young scientists

- Build a network!

- Find a balance between
  - **exploring** your research interest
  - being **useful** to your group
  - improving your **CV**

- Time management
  - *You have more to offer than your 100% availability!*

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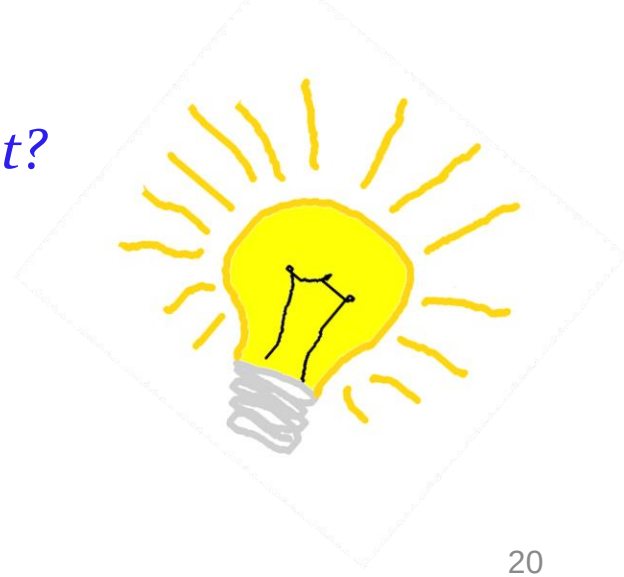
My view on grant-based research

- Important with alternative paths in the academic system
- Possibility for young scientists to become group leaders
- Greater chance to succeed if you have a clear **narrative**
  - *What is special about your idea?*
  - *Why are you the best person to pursue it?*
  - *Why will it work?*

Take the training you are offered!



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My advice to senior scientists

- Set a goal, *e.g.* to do something every year to **promote diversity**
  - *…but do not work for free*.

- Be the change you want to see!
  - How do you **recruit**?
  - How is the **work environment** in your group?
  - How do you **support** young scientists?
  - Can you deal with **competition**?

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Thanks for your attention!

Knut and Alice Wallenberg Foundation

Swedish Research Council

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