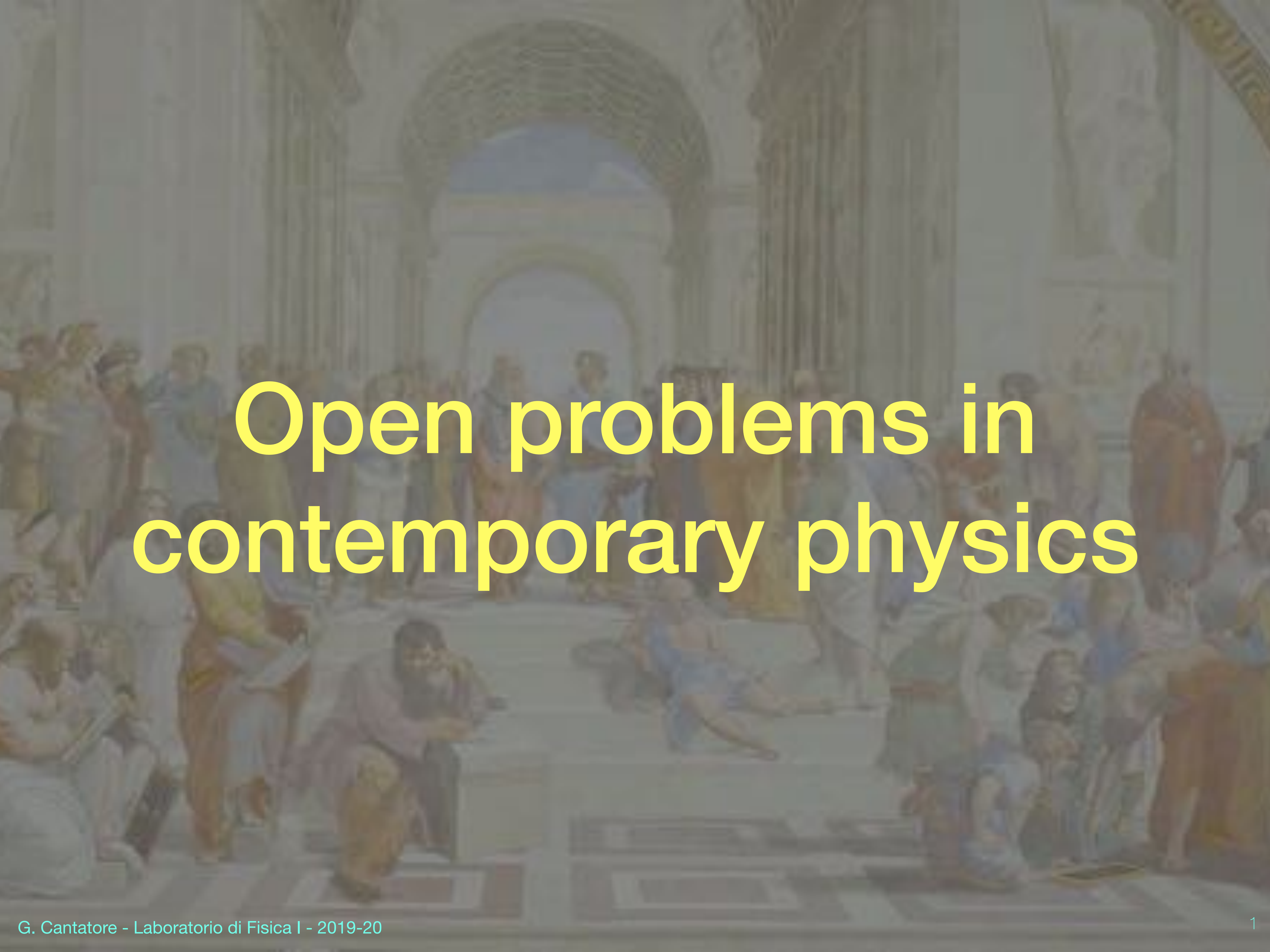
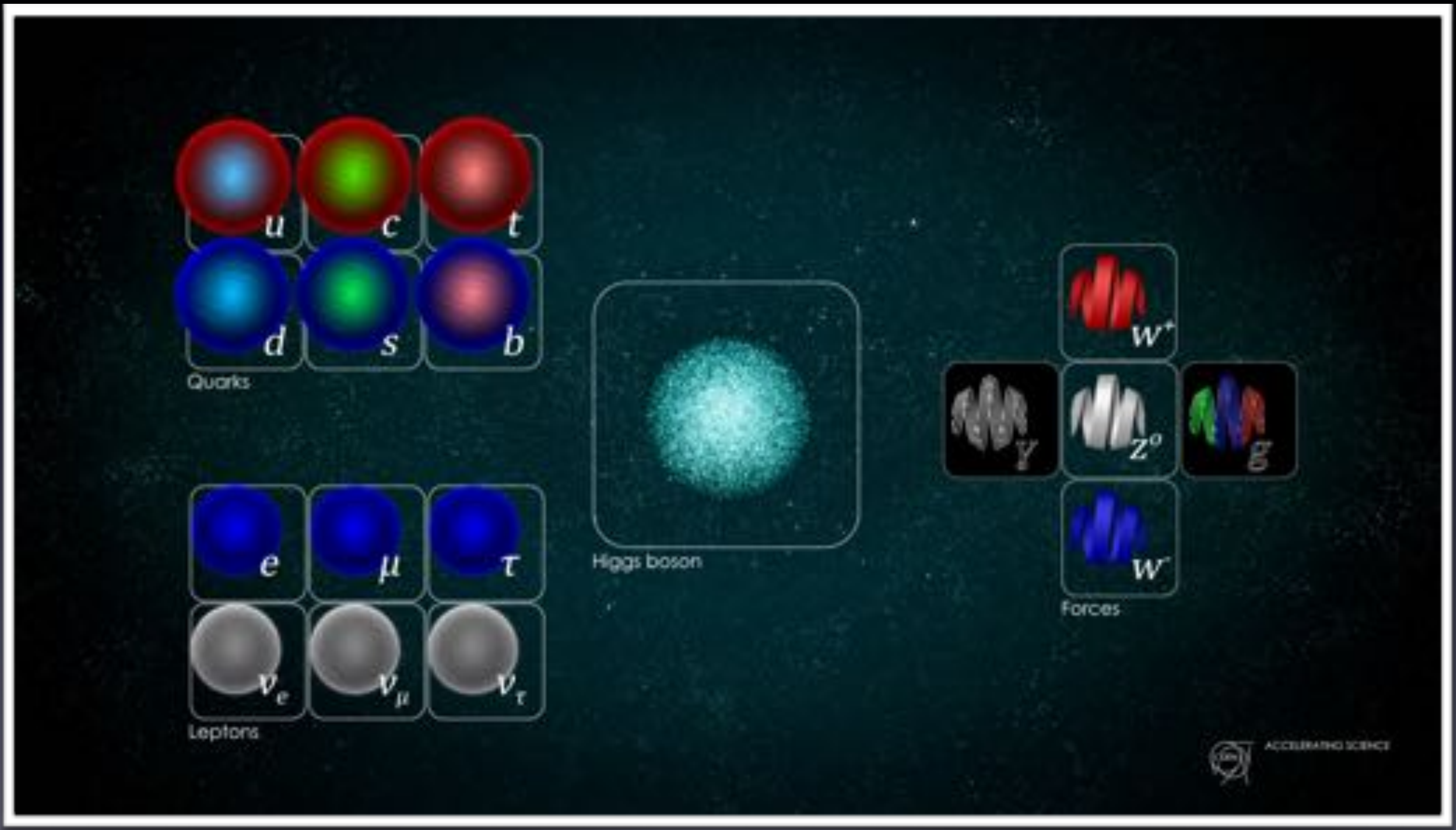


Open problems in contemporary physics

The Standard Model



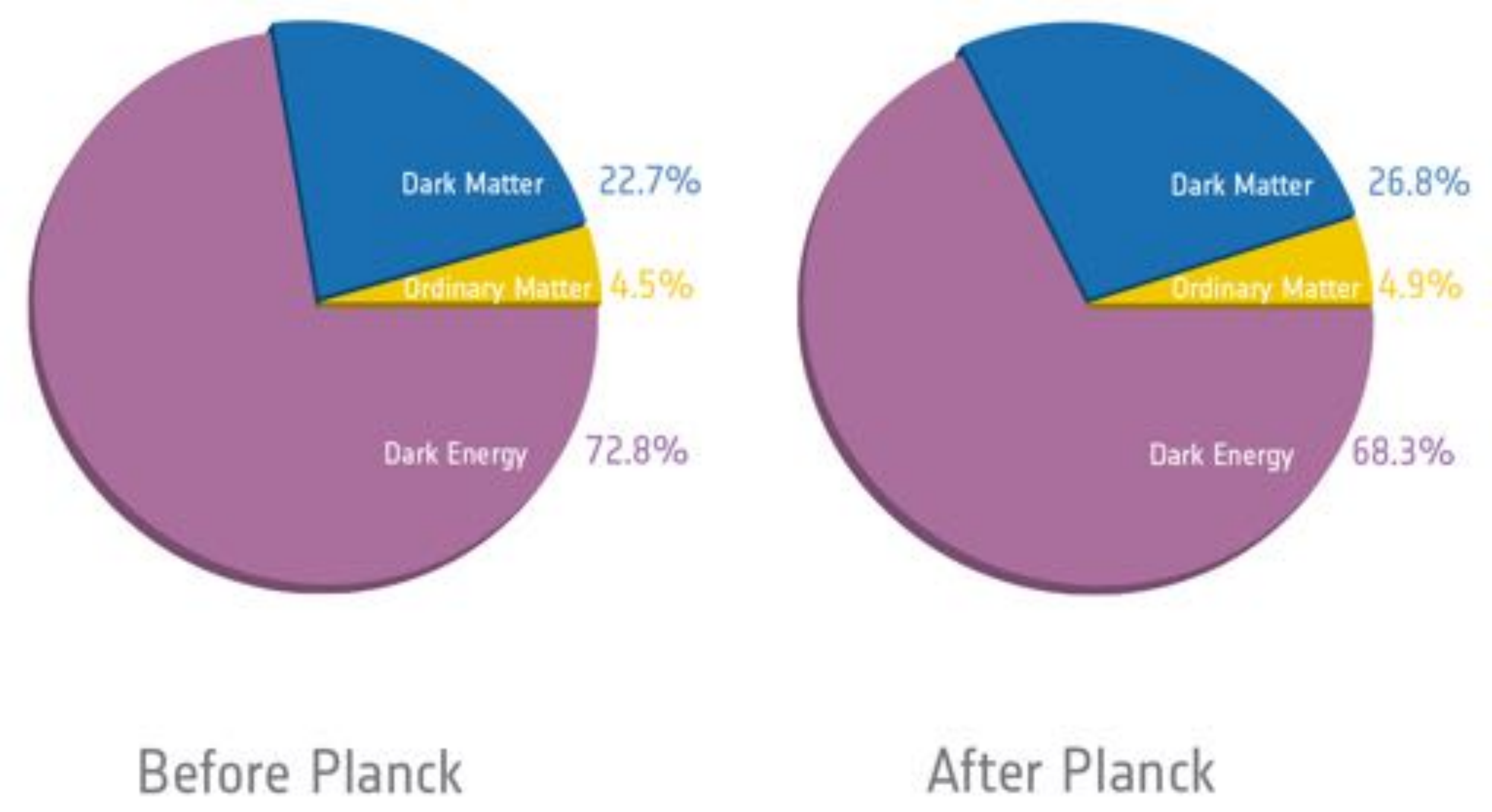
Some of the problems with the Standard Model (SM)

- Gravity is not included
- Large number of free parameters (particle masses and interaction strengths)
- $(g-2)_\mu$ deviates from the SM prediction
- "Fine-tuning"
  - "θ parameter" or CP conservation in strong interactions
  - …
- …

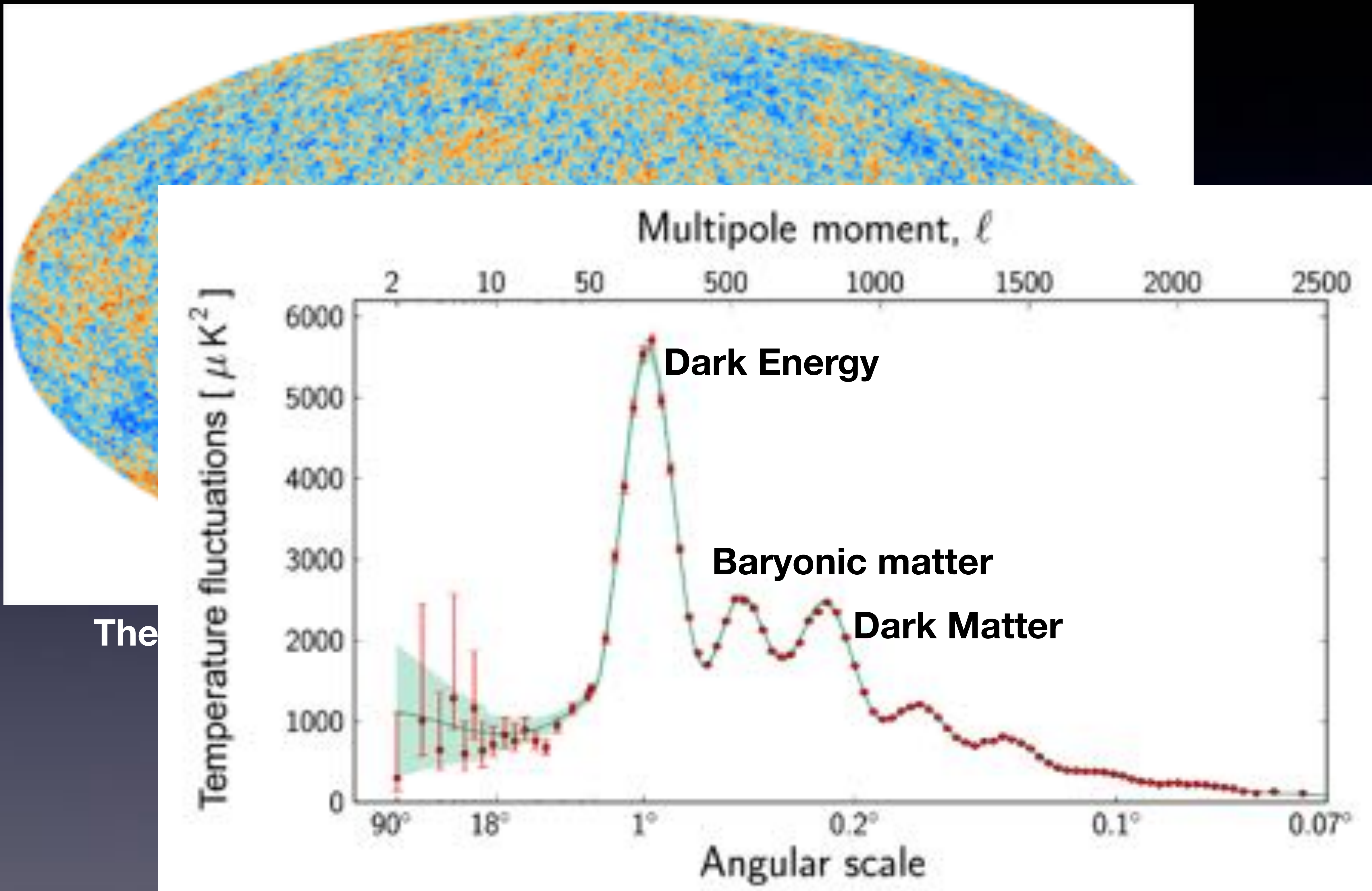
Cosmology: hints and puzzles

- Matter-antimatter asimmetry
- Composition of the Universe
- …

Energy makeup of the Universe



Latest measurements from the Planck satellite



The

Power Spectrum of the CMB fluctuations

“Frontiers” in physics

Energy Frontier

- use high-energy colliders to search for new particles and forces that provide information on the makeup of matter and space

Intensity Frontier

- generate a huge number of events to study rare processes $\Rightarrow$ **it requires highly precise experiments**

Cosmic Frontier

- scan the heavens with telescopes and **highly sensitive detectors** to learn more about cosmic rays, dark matter, and dark energy

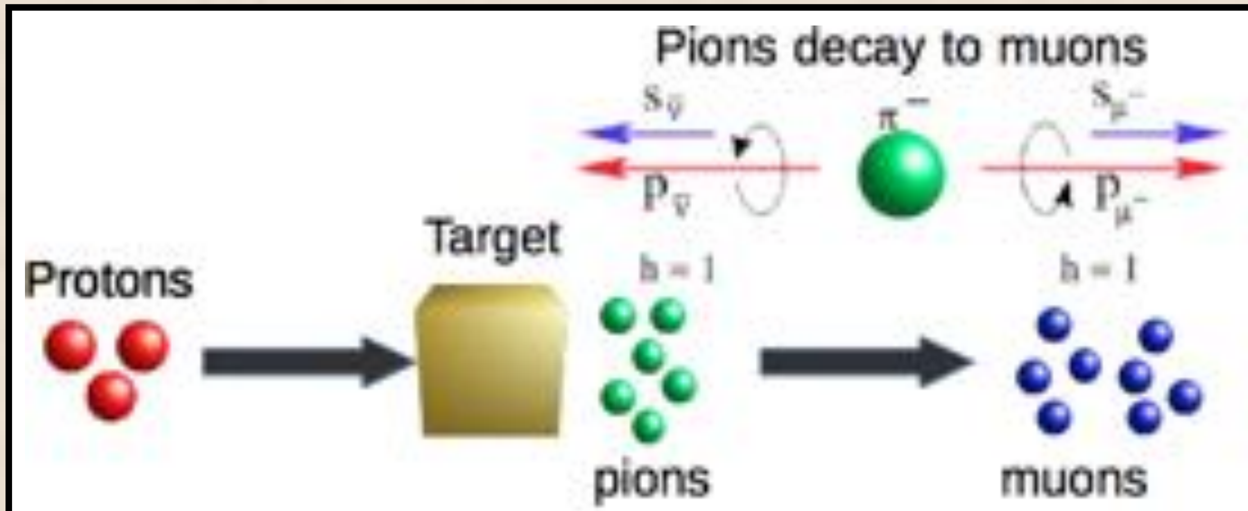
Precision Physics

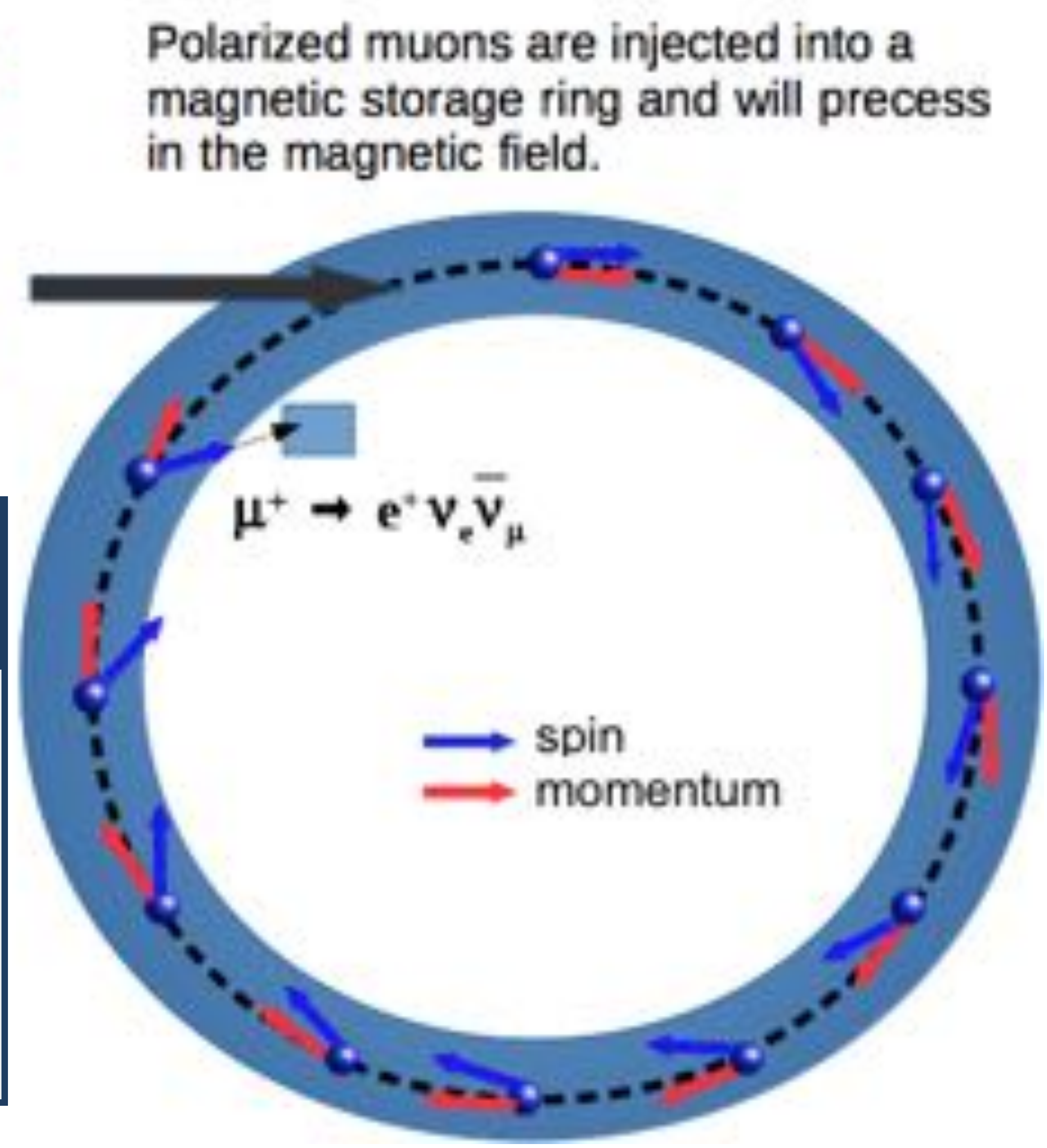
- **"Precision Physics" plays a key role in the Intensity and Cosmic Frontiers**
- Examples of precision physics techniques
  - interferometry
  - optomechanical sensors
  - polarimetry
  - RF & microwave measurements
  - single photon detectors (example: TES sensors)
  - cryogenics
  - …
- **"Small scale"** laboratories and **"table top"** set-ups are the ideal places to develop and test **Precision Physics** techniques (and also to do experiments!)

Intensity frontier: the $(g\text{-}2)_\mu$ anomaly

a_μ measurement method

$$a_\mu = \frac{g_\mu - 2}{2}, \qquad \vec{\mu}_\mu = g_\mu \frac{q_\mu}{2m_\mu}\vec{S}_\mu$$





measure rotation of spin w.r.t. momentum for a muon rotating in a magnetic field

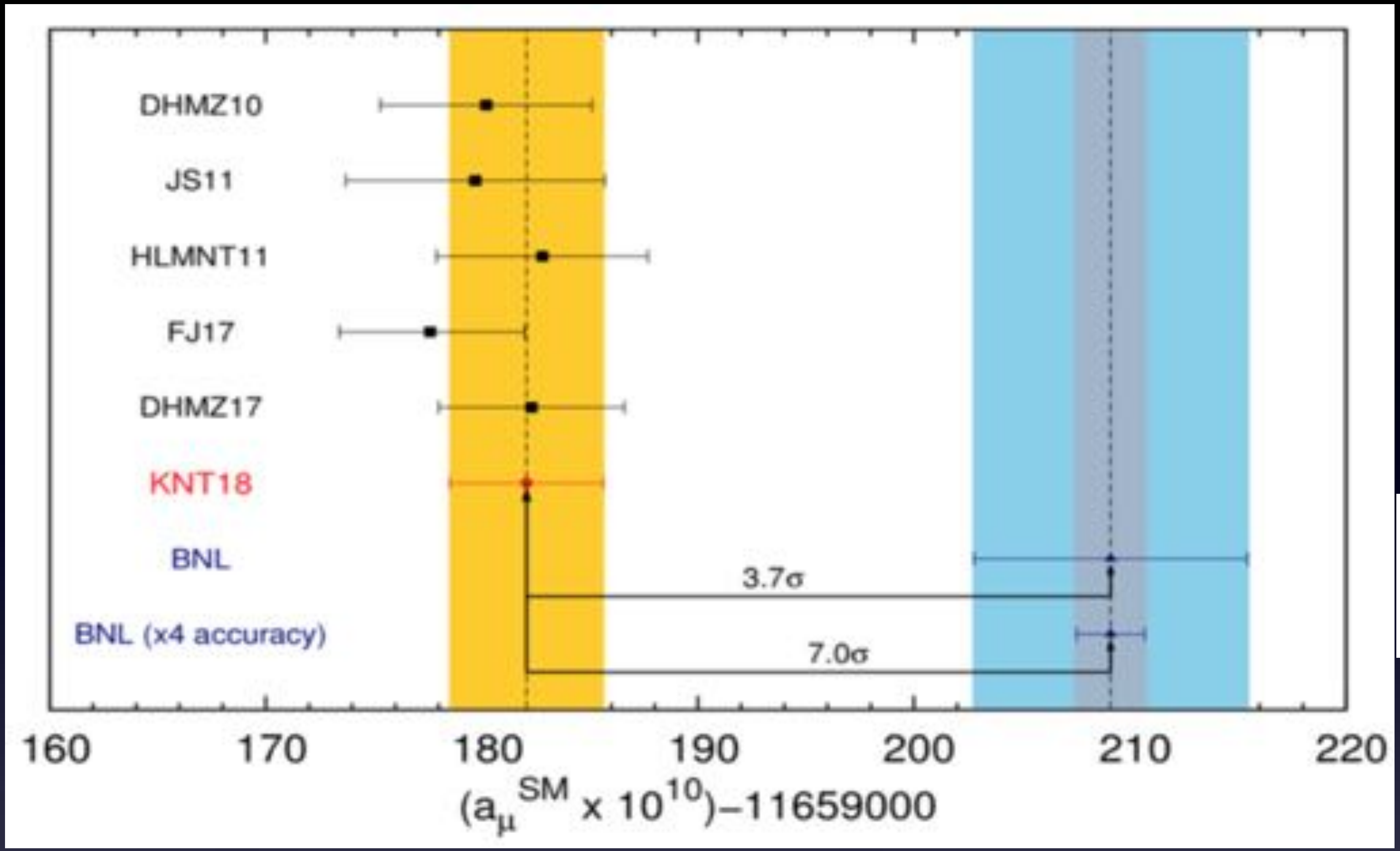
$$\omega_s - \omega_c = \omega_a$$

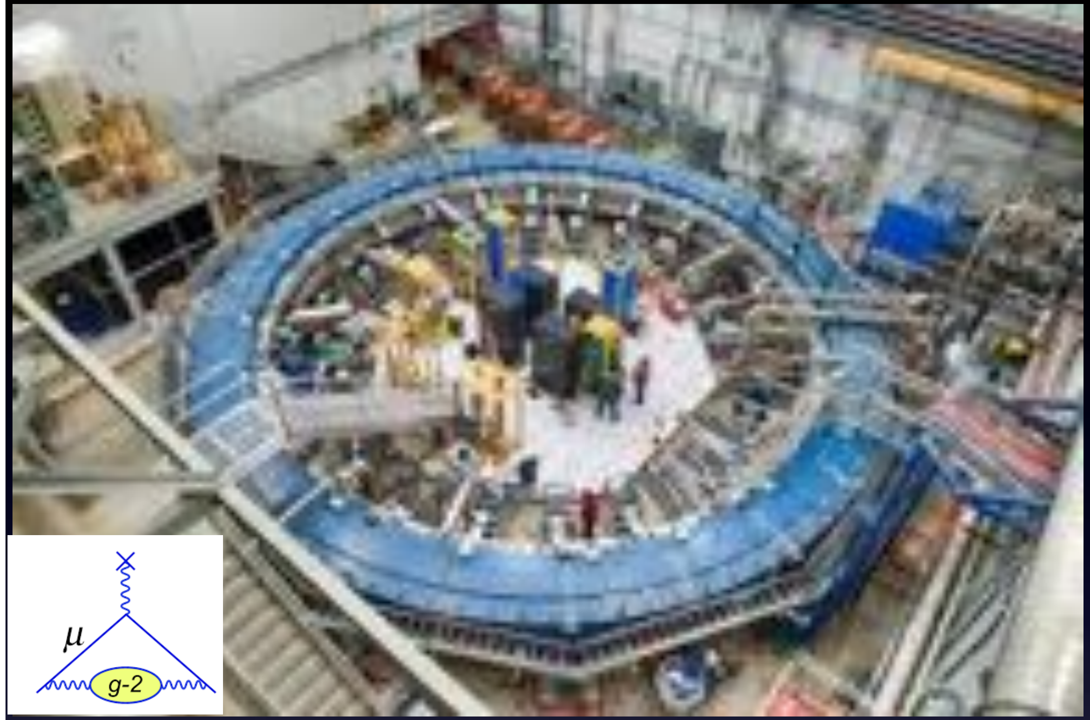
$$-g_\mu \frac{eB}{2m_\mu} - (1-\gamma)\frac{eB}{m_\mu \gamma} - \left(-\frac{eB}{m_\mu \gamma}\right) = a_\mu \frac{eB}{m_\mu}$$

Larmor + Thomas precessions — cyclotron frequency — no γ!

slide courtesy of A. Lusiani - INFN Pisa

Muon g-2 at Fermilab - E989

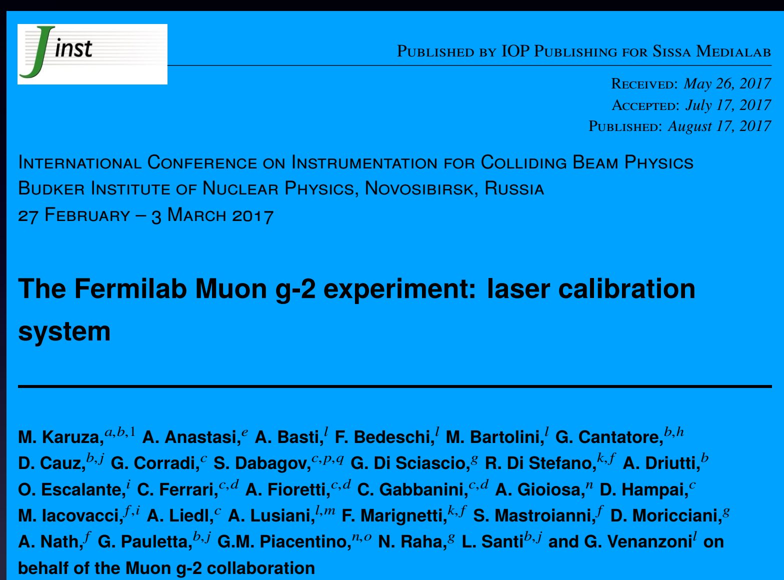




- 2001 BNL experiment measures a deviation of $(g\text{-}2)_\mu$ from the SM prediction at the level of ~3σ
  - possible signature of new non-SM particles hiding in the vacuum and invisible at colliders because of their mass
- Goal of E989 at Fermilab: confirm (or refute…) the deviation at the level of 7σ ⇒ it would be a major discovery!
  - increase 20-fold the statistics with respect to BNL (Intensity Frontier)
  - 4-times better precision than BNL (Precision Physics)

INFN contribution to g-2

- The INFN group within “g-2” is responsible for the laser calibration system of the electron calorimeters
- It is a critical element towards the goal of reducing the overall uncertainty
- **Precision physics at work!**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The Fermilab Muon g-2 experiment: laser calibration system

M. Karuza,[a,b,1] A. Anastasi,[e] A. Basti,[f] F. Bedeschi,[f] M. Bartolini,[l] G. Cantatore,[b,h] D. Cauz,[b,j] G. Corradi,[c] S. Dabagov,[c,p,q] G. Di Sciascio,[g] R. Di Stefano,[k,f] A. Driutti,[b] O. Escalante,[i] C. Ferrari,[c,d] A. Fioretti,[c,d] C. Gabbanini,[c,d] A. Gioiosa,[n] D. Hampai,[c] M. Iacovacci,[f,i] A. Liedl,[c] A. Lusiani,[l,m] F. Marignetti,[k,f] S. Mastroianni,[f] D. Moricciani,[g] A. Nath,[f] G. Pauletta,[b,j] G.M. Piacentino,[n,o] N. Raha,[g] L. Santi[b,j] and G. Venanzoni[l] on behalf of the Muon g-2 collaboration

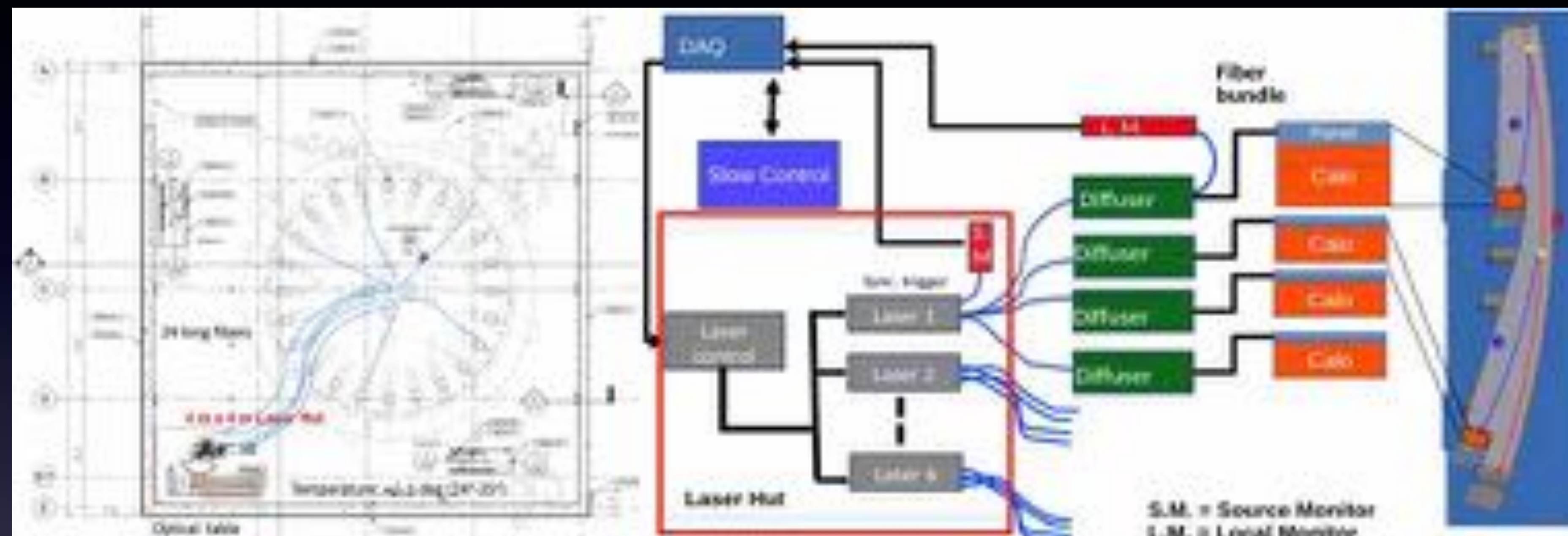
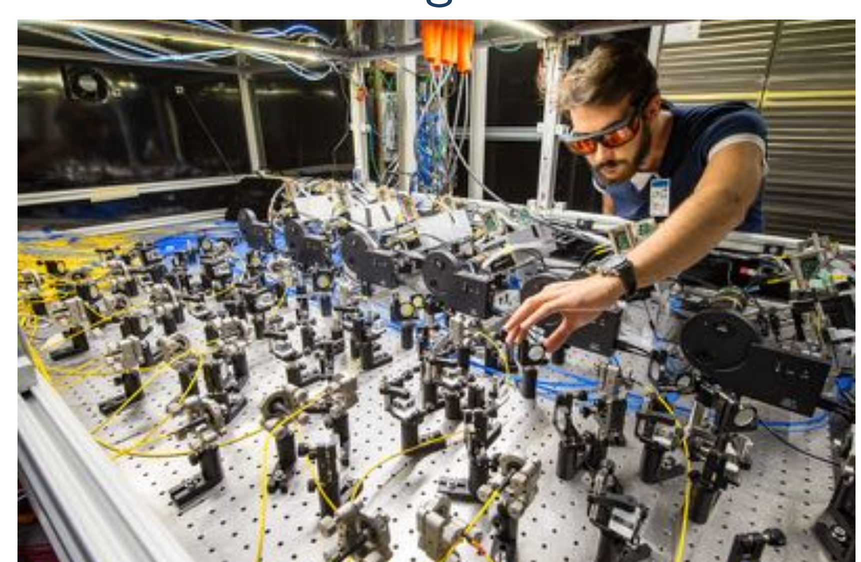


Table 2. Contribution of various processes to magnetic moment anomaly.

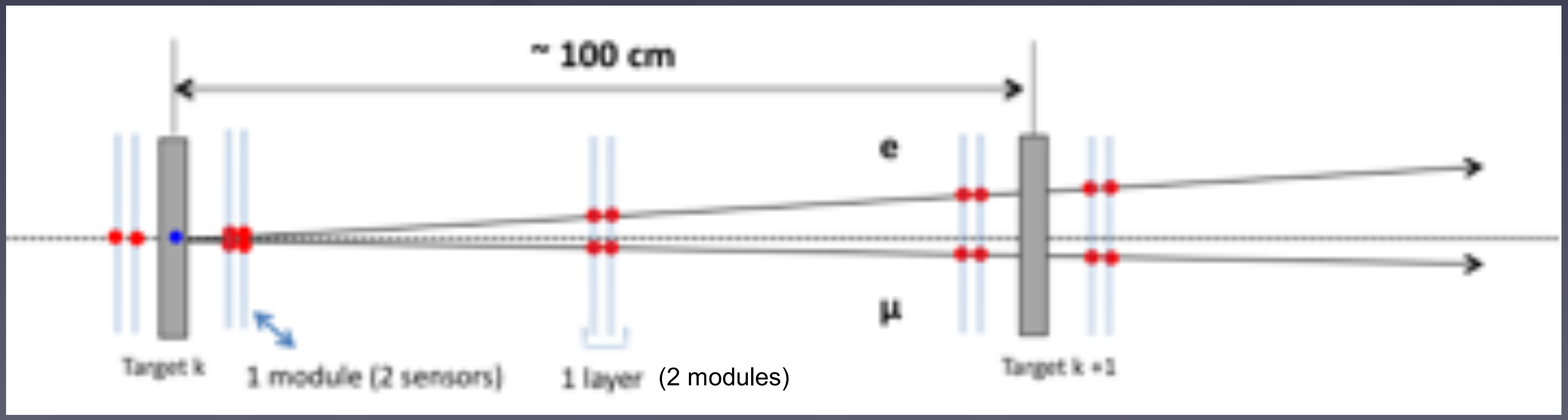
CATEGORY	Brookhaven (ppb)	Fermilab	Goal (ppb)
Gain changes	120	Better laser calibration, low energy threshold	20
Pileup	80	Low energy samples recorded, calorimeter segmentation	40
Lost muons	90	Better collimation in ring	20
Coherent betatron oscillation	50	Higher n value (frequency), Better match of beamline to ring	<30
E and pitch	50	Improved tracker, Precise storage ring simulations	30
Total	180	Quadrature sum	70

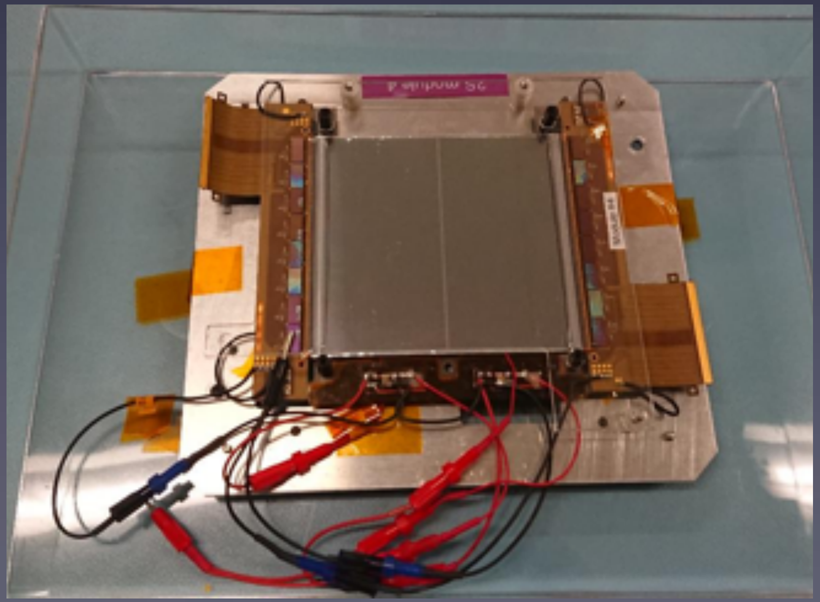
laser calibration system monitors calorimeter gain to 10^{-4}



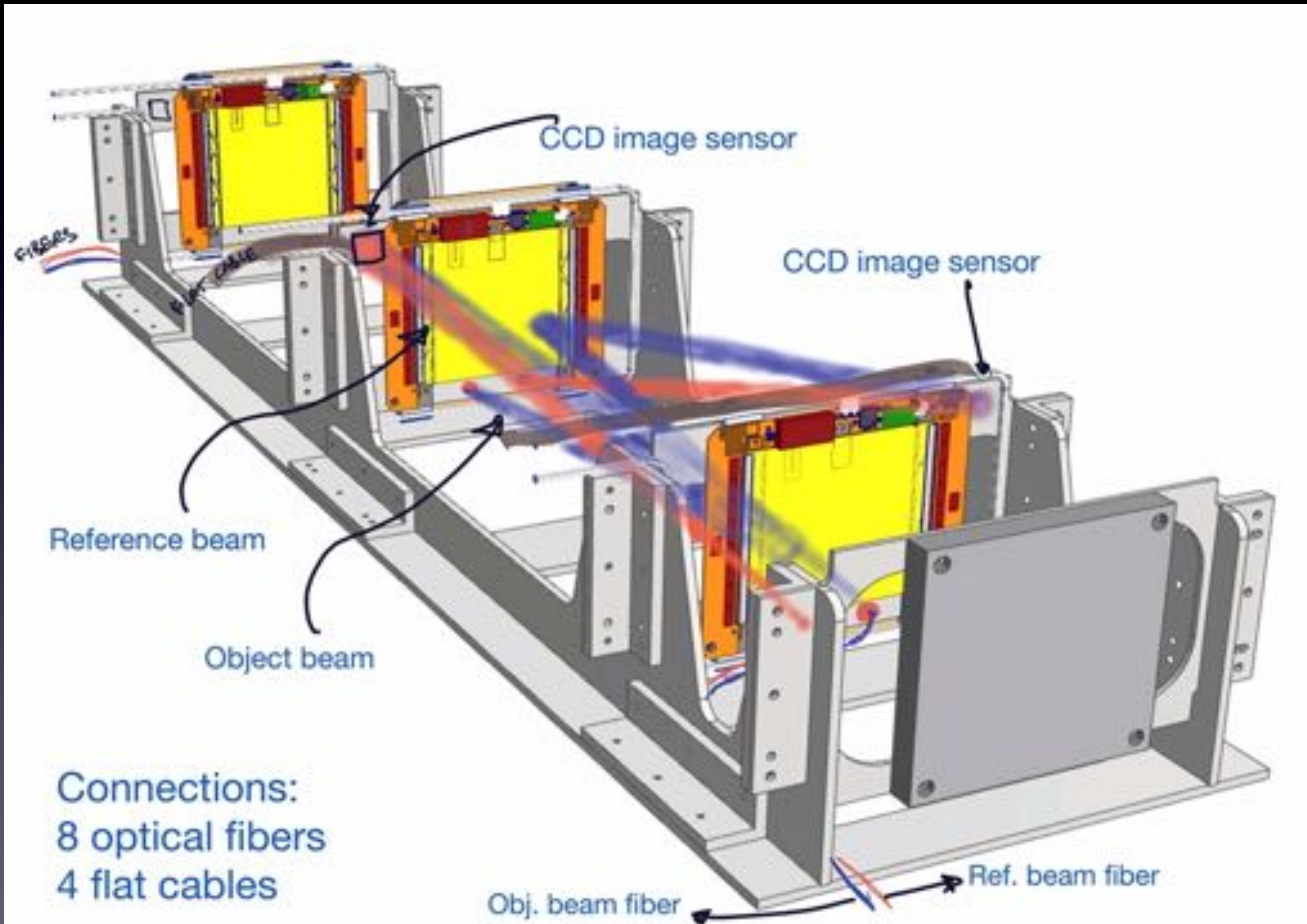
MUonE at CERN - INFN project

- MUonE project: precision measurement of the muon-electron scattering angle to extract directly the hadronic contribution to g-2
- Beamline at CERN: muon beam on an electron target, elastic scattering measured with a series of detector stations equipped with tracking planes
- Challenge (on of many…)
  - monitor the relative alignment of the tracking planes at the level of 10 μm
- Solution:
  - real time holographic interferometry
- Objective: be ready for a test beam at CERN in 2021

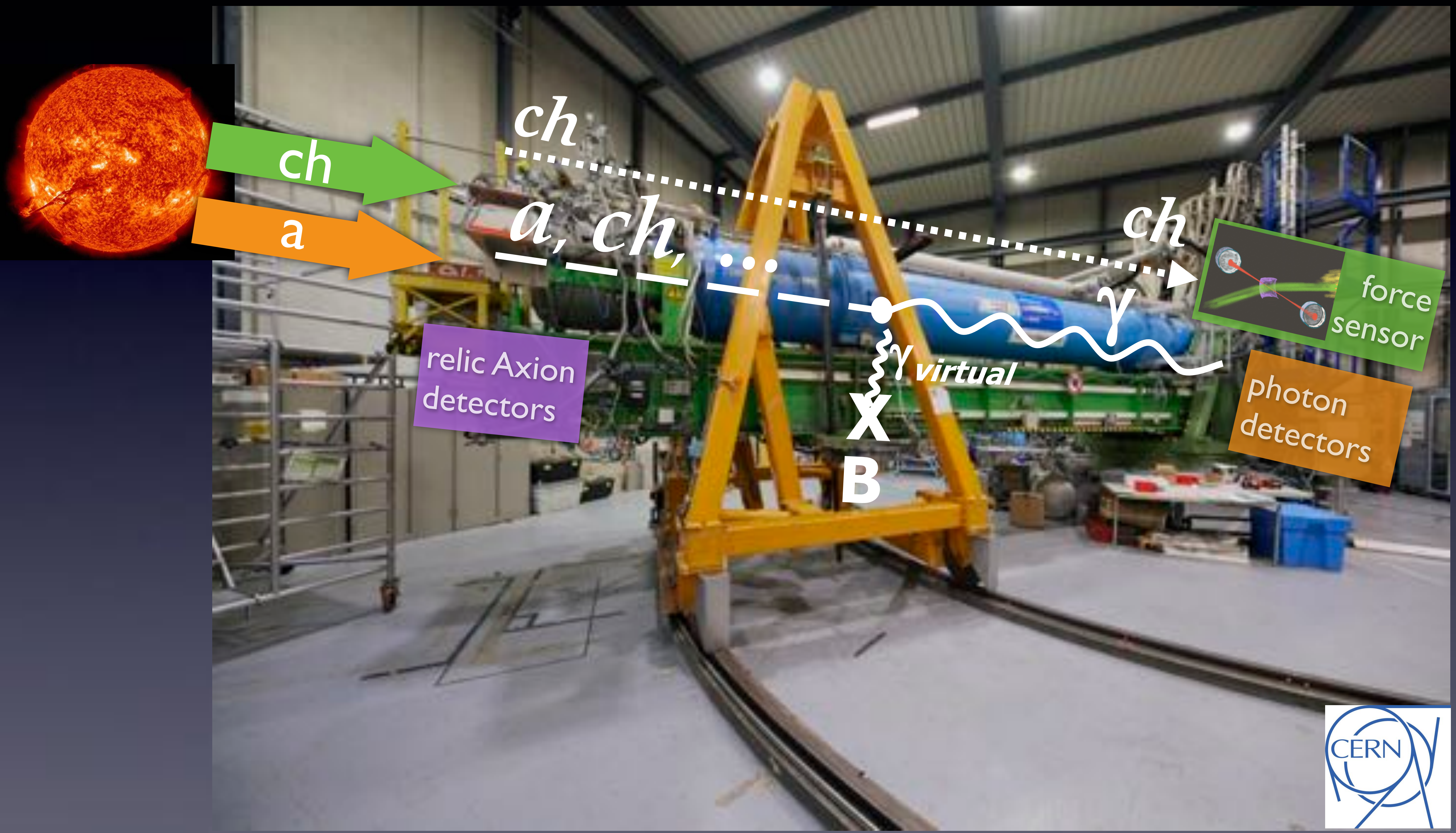




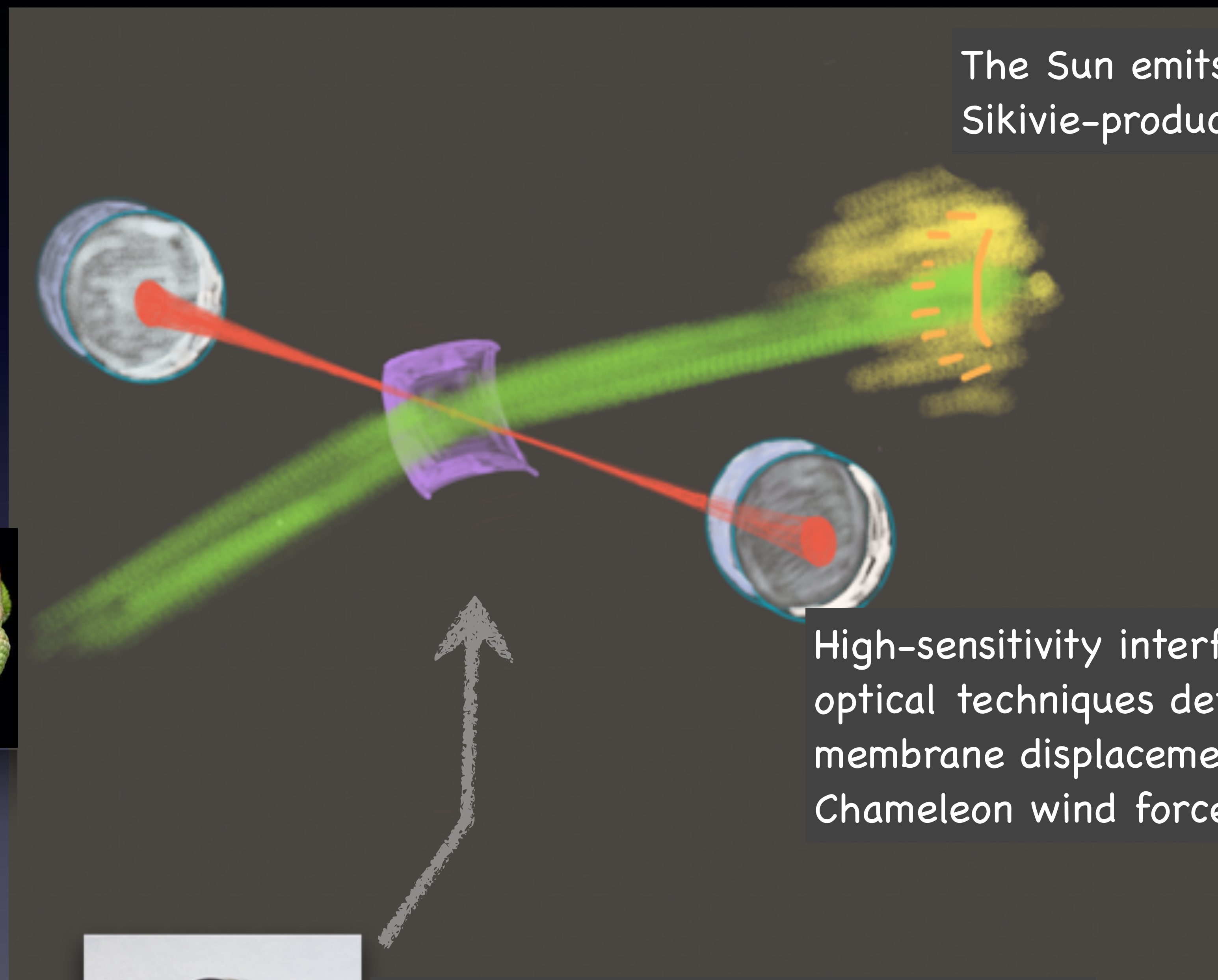
Holographic Alignment Monitor for MUonE



The CAST helioscope



The Kinetic WISP detection principle



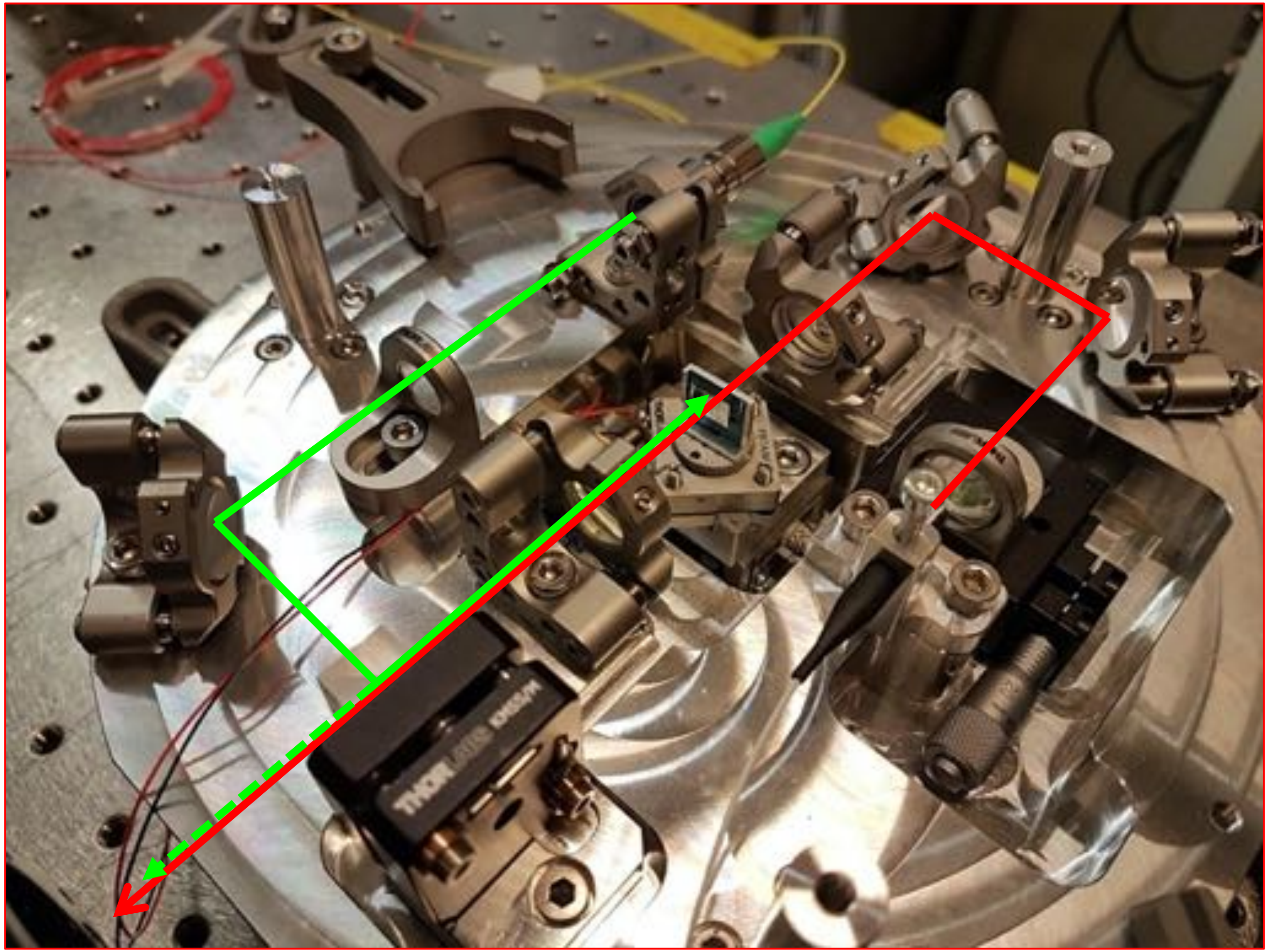
The Sun emits a stream of Sikivie-produced Chameleons

High-sensitivity interferometric optical techniques detect tiny membrane displacements due to the Chameleon wind force

An ultra-thin taut membrane flexes as a sail under the Chameleon wind

Curious? See January-February 2016 CERN Courier http://cerncourier.com/cws/article/cern/63705

KWISP 3.5 – Triest lab tests



KWISP 3.5 – Triest lab tests

Detector assembly and tests:

- Prepared the detector for vacuum tests