Low x series of meetings: A journey to understand the proton

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Low x, High School meeting, Gyongyos, June 10 2016

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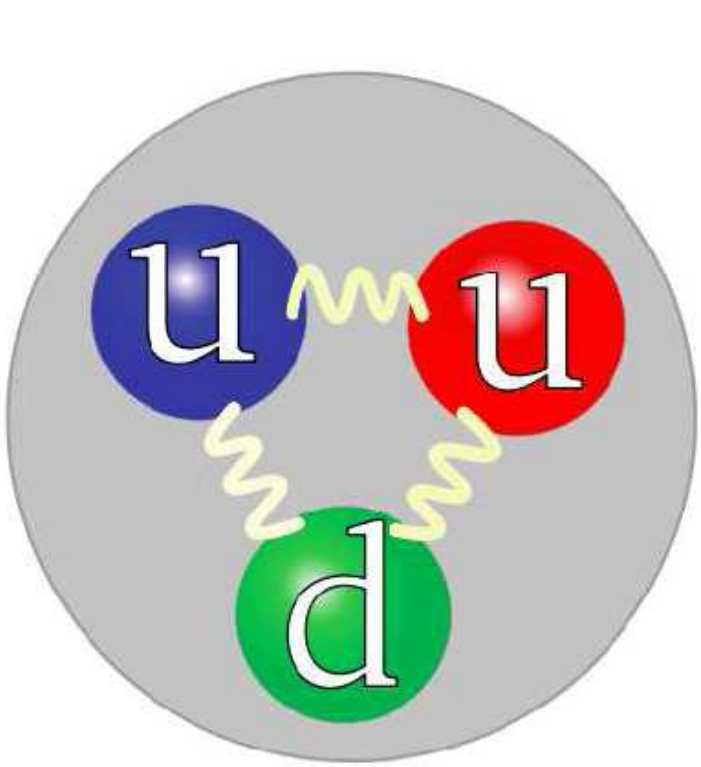
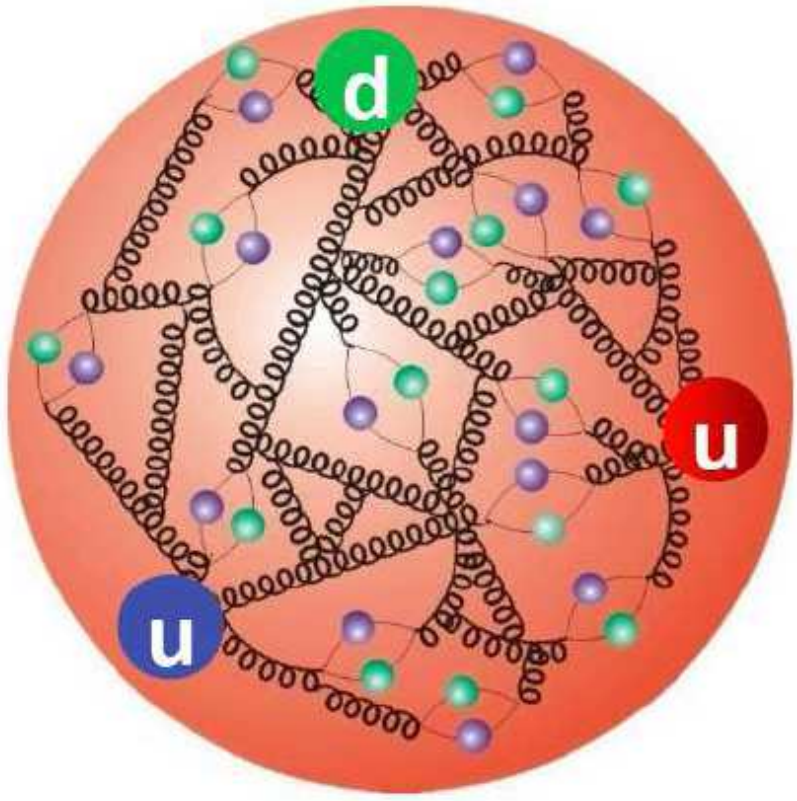
- The future: LHC...

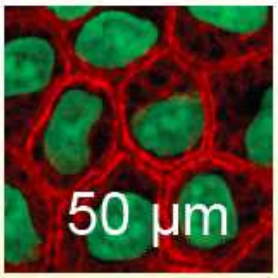
The starting point: what is a proton?





- Electron-proton and proton-proton colliders exist, so what are protons?
- Protons are constituent of nuclei. They are small and have a size of $\sim 10^{-15}$m (1 fermi), about 1/100000 of the size of a hydrogen atom
- They consist of 3 valence quarks and many gluons and sea quarks bound together by nuclear (strong) interactions
- Most of the proton mass comes from its energy: $E = mc^2$

Scales and tools



10^{-6}

Extra magnification?

Cells
Five hundred per inch

Microscope

10^{-9}

x 25 thousand

DNA
Ten million per inch

Electron Microscope

10^{-15}

x 1 million

Nucleus
Ten thousand billion per inch

Particle Accelerators

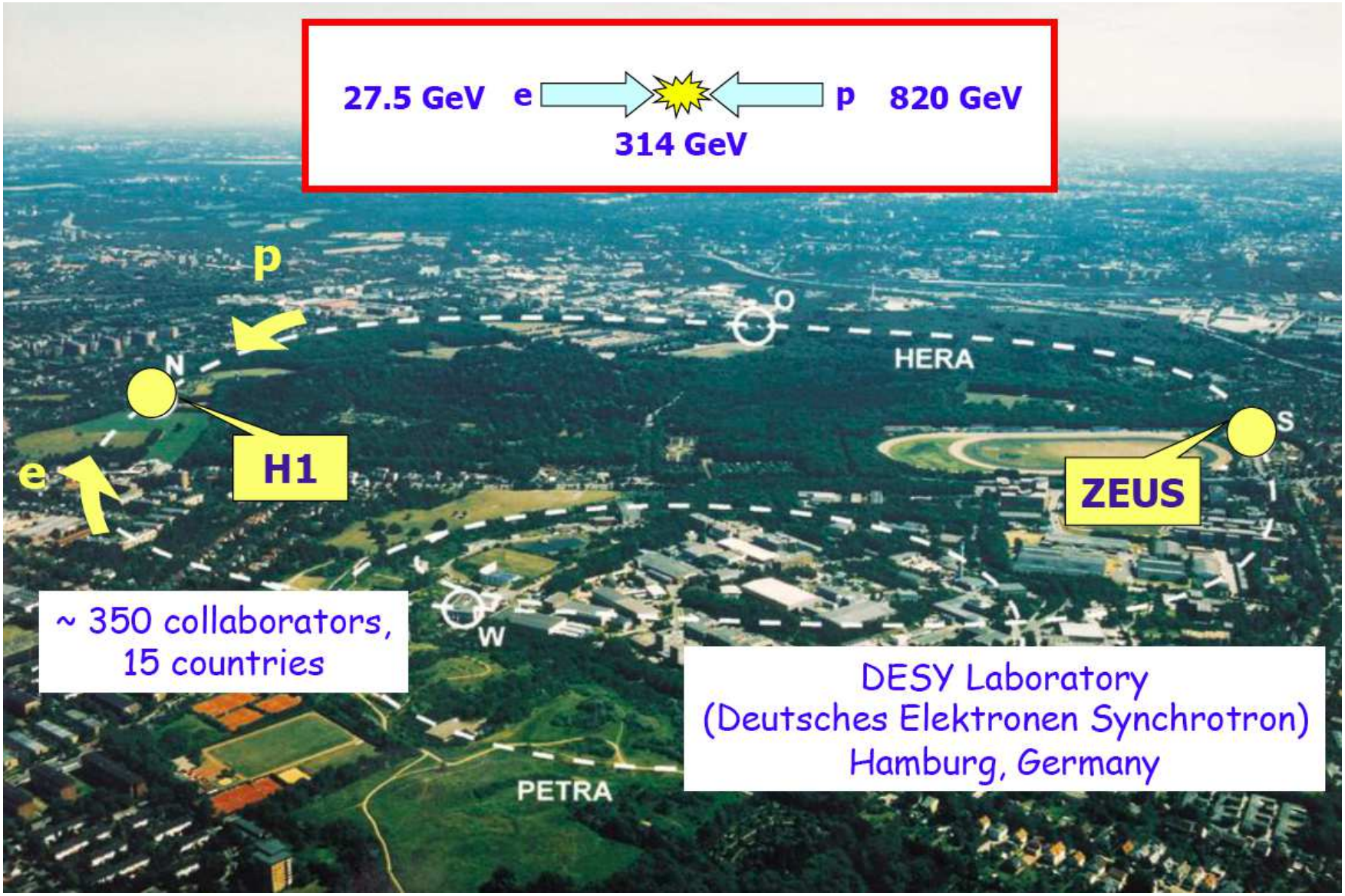
10^{-18}

x 2 thousand

Quarks
> 100 million billion per inch

The H1 experiment at DESY, Hamburg: ep collider

- HERA: electron proton collider
- Two main experiments (H1 and ZEUS)
- The electron allows to probe the proton substructure (the electron is an elementary particle): proton structure in terms of quarks and gluons

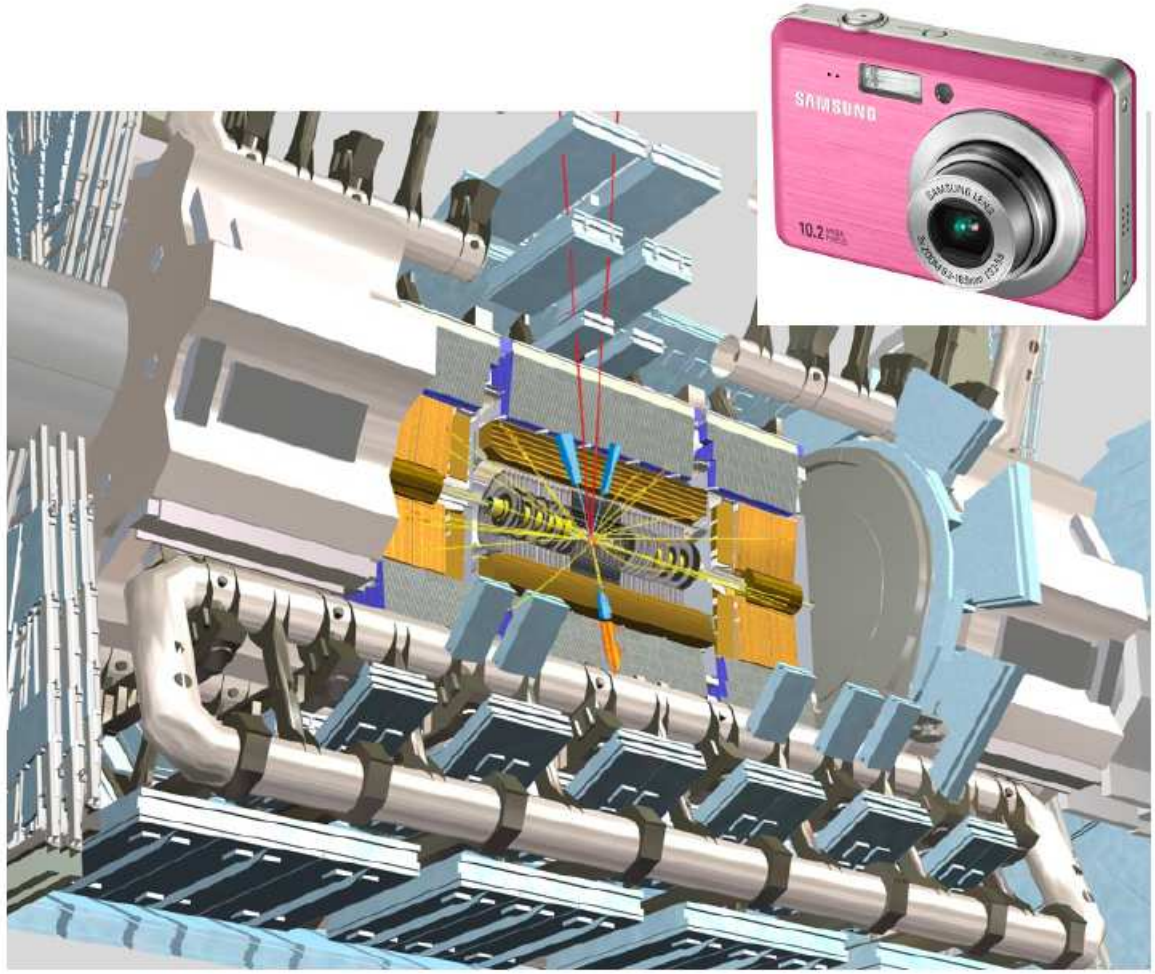


The idea of a detector in particle physics

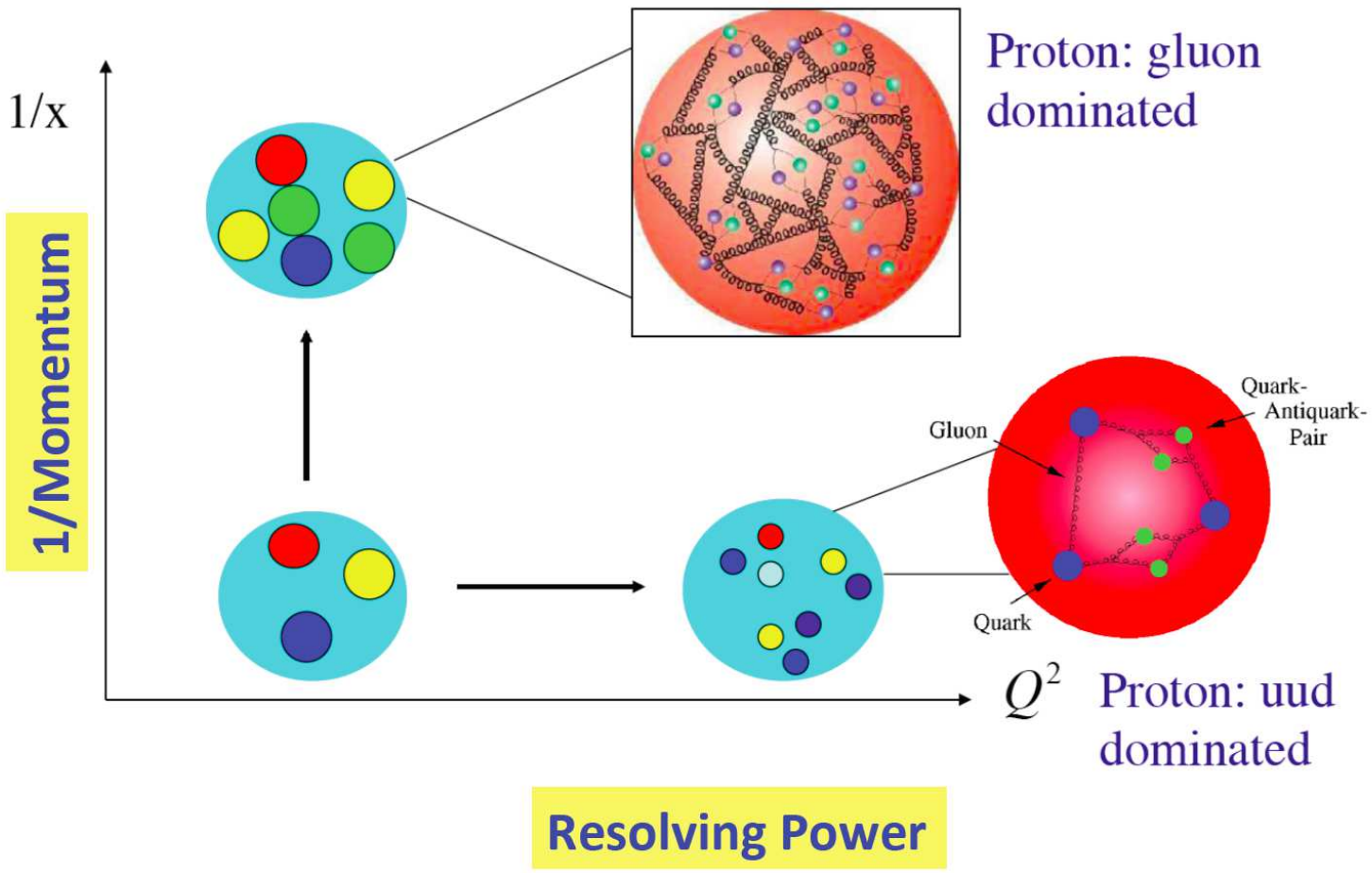
Largest scientific instruments ever built to track particles with micron precision over ~50m length with ~100 million electronic readout channels.

These detectors are similar to digital cameras, but taking pictures at a rate of 40,000,000 / second.

They are sensitive to light and all other radiations.



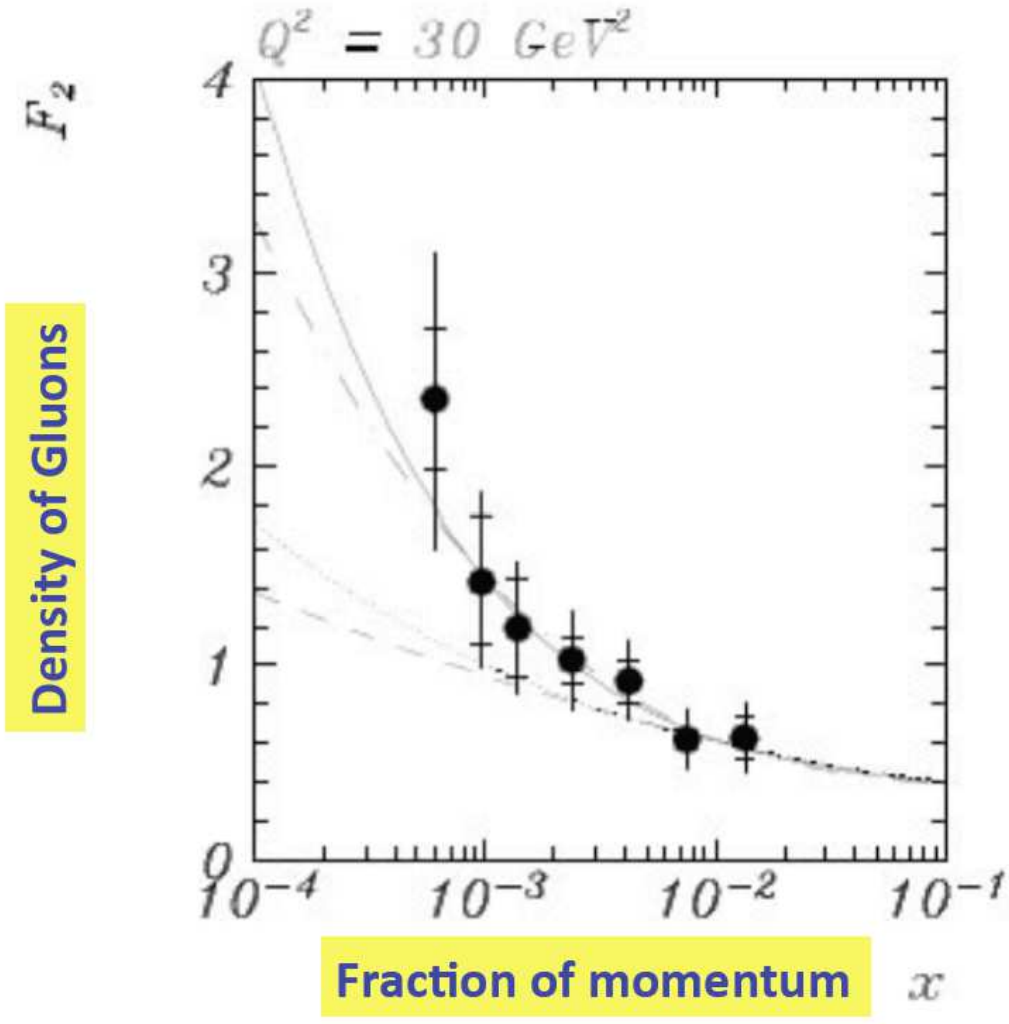
The proton structure



- The proton is a complicated object: it appears differently according to its energy (quantum object)
- Q^2: Resolution power (like a microscope): *the higher the energy of an accelerator is (bigger machines), the higher values of Q^2 (the resolution) and the smaller distances that we can reach*
- x: momentum fraction of the proton possessed by the quark/gluon (proton constituent)

Proton structure at HERA

- Discovery: High gluon density in the proton at small x!
- Starting point of 'Low x" series of workshops in 1992
- Discovery of large gluon density in the proton
- Leading to many results/publications in this new field of strong interaction



History of low x meetings

- 1992: first meeting between theorists and experimentalists in Saclay (I was starting my PhD!)
- I was volunteered to organize the series of meetings starting in 1993, the first one being in France, close to Paris (mainly dedicated to French physicists)
- The meeting became international very fast: German and British people asked to join the meetings, and the second/third/fourth meetings took place in DESY, Hamburg; Cambridge, UK; Durham, UK
- The meeting extended further with participants originating from all over the world, the specificity of the meetings is the large amount of time devoted to discussions between participants
- Low x meetings occured in Spain (Madrid, Santiago de Compostela), Italy (Ischia), Greece (Nafplio, Crete, Kavala), Japan (Kyoto), Germany (Berlin), Portugal (Lisbon), Israel (Tel Aviv, Eilat), Cyprus, Berlgium (Antwerp), Finland (Helsinki), Czech Republic (Prague), Poland (Cracow, Sandomiercz)... and this is the first time in Hungary

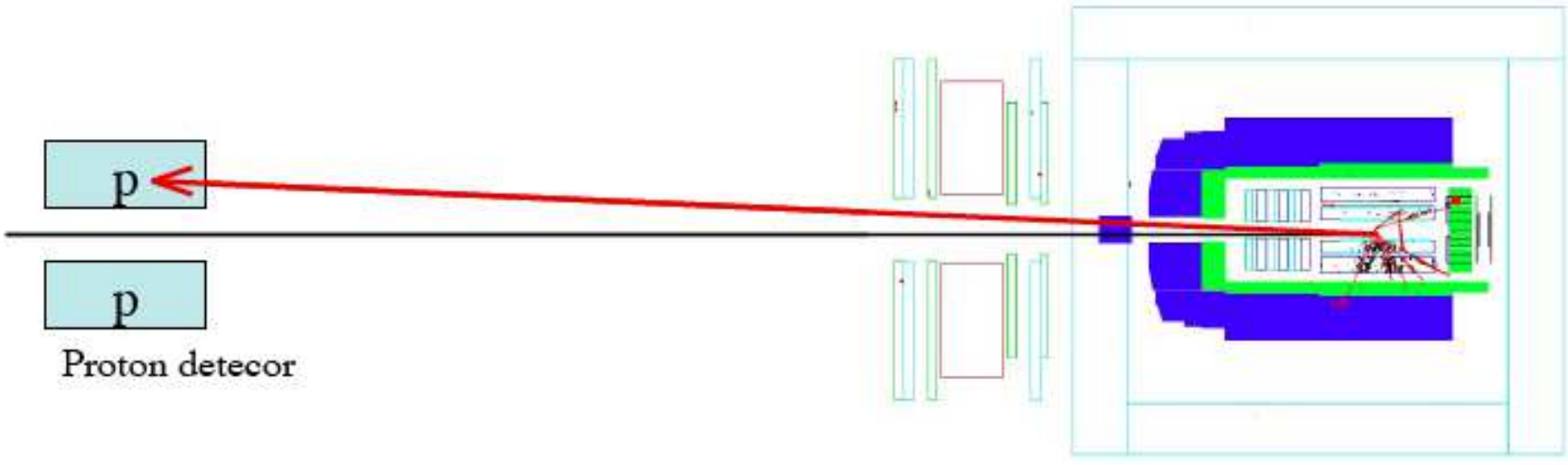
Collaboration with Hungary: towards a long and successful collaboration!

- Everything started within the TOTEM Collaboration where both Tamas and myself are members
- Propose some collaborations first with France (where I was until December 2015) and now the USA: Exchanges of Professors/students
- Collaboration at the university level: Gyongyos, Christophe is now associated to Gyongyos as an Honorary Professor
- Last but not least: PhDs in coleadership: David Lucsanyi interested in being a graduate student towards PhD both in Hungary and USA

Present and future: LHC: Exploration of a New Energy Frontier

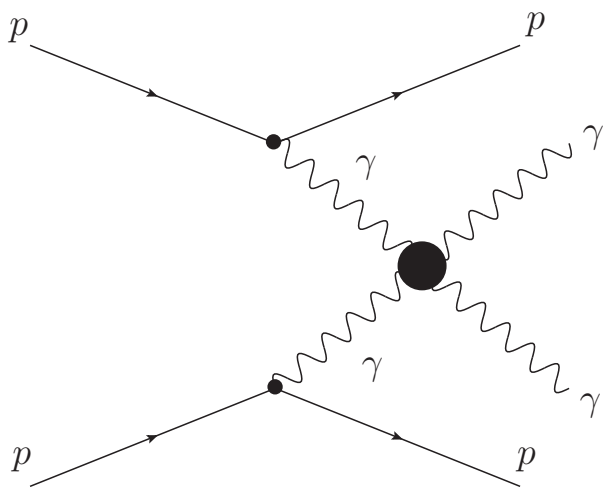
- The Large Hadron Collider (LHC) collides protons of energies 3.5-4 TeV (before 2014), and 6.5 TeV (starting now): 6.5 times more than the Tevatron
- Access both to low x and high x domains: high gluon densities, and more sensitivity to quark substructure
- Forward Physics LHC Working Groups: Fruitful collaboration with Hungary, USA (the University of Kansas), about diffraction (contribution to the reference book on this physics that I was coordinating, TOTEM collaboration)

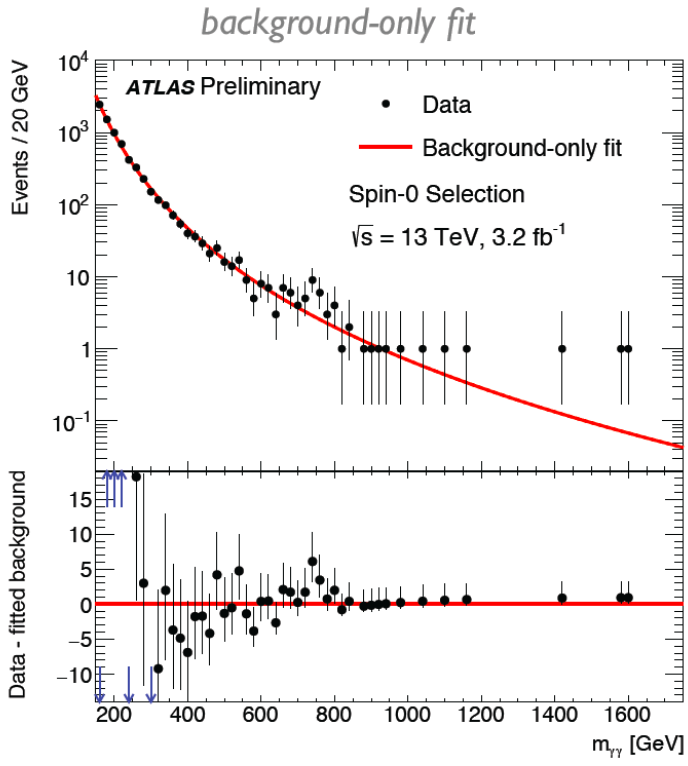
The proton structure is even more complicated: discovery of surprising events at HERA!

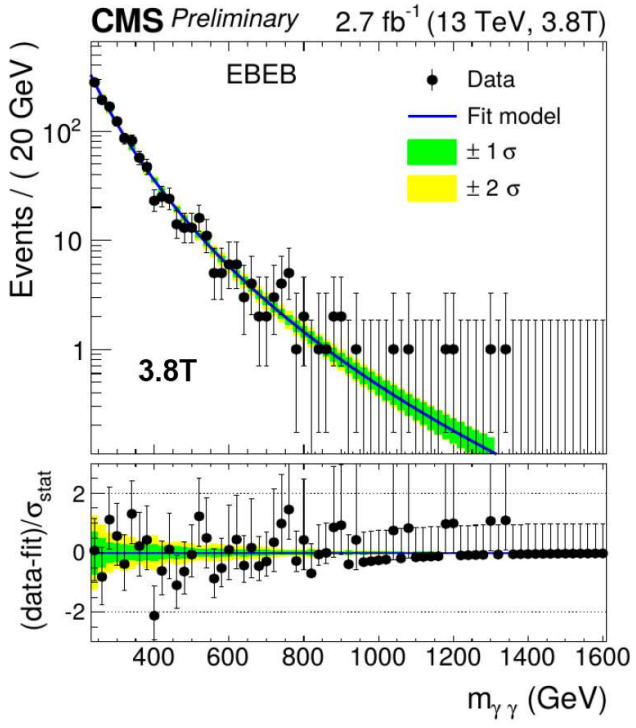


- Some strange events can be produced where the proton is not destroyed! The proton loses part of its energy
- These events are observed in electron-proton and proton-proton colliders
- An everyday analogy would be an accident between two large trucks (the protons) that lead to the two intact trucks and additional small cars!
- Leads to a new field of research at the LHC: measuring intact protons in the final state, in the TOTEM detectors (Hungary)
- All these topics will allo further exchanges between Hungary and France/USA: Students are very much welcome to join this great and successful program and collaboration!

CMS and ATLAS observation: Towards a discovery?





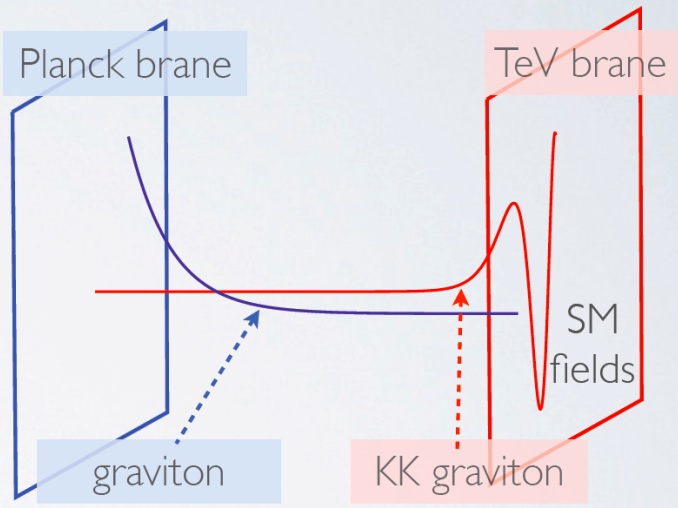


Warped extra-dimensions

✘ Warped Extra Dimensions solve hierarchy problem of SM

✘ 5th dimension bounded by two branes

✘ SM on the visible (or TeV) brane



✘ The Kaluza Klein modes of the graviton couple with TeV strength

$$\mathcal{L}^{\gamma\gamma h} = f^{-2}\, h^{\rm KK}_{\mu\nu}\, (\tfrac{1}{4}\eta_{\mu\nu}F^2_{\rho\lambda} - F_{\mu\rho}F_{\rho\nu})$$

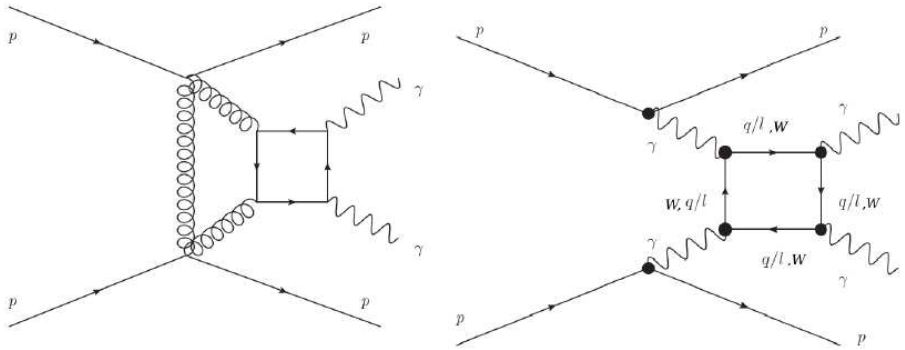
$$f \sim \text{TeV} \qquad m_{\rm KK} \sim \text{few TeV}$$

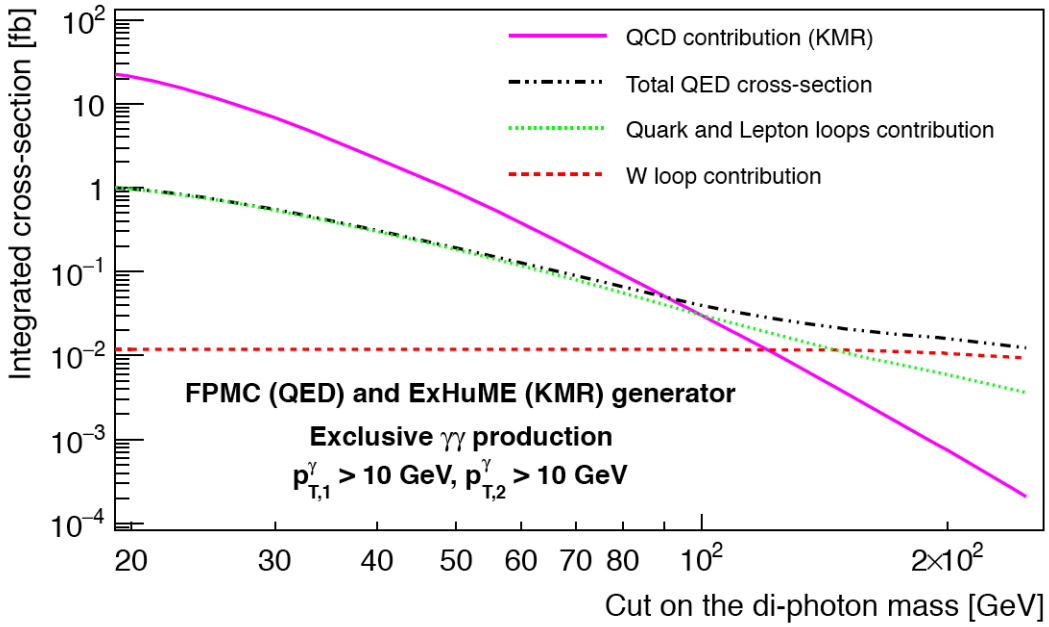
✘ Effective 4-photon couplings $\zeta_i \sim 10^{-14} - 10^{-13}\ \text{GeV}^{-2}$ possible

✘ The radion can produce similar effective couplings

- Beyond standard models predict anomalous couplings of $\sim 10^{-14}$-10^{-13}
- Work in collaboration with Sylvain Fichet, Gero von Gersdorff: Phys.Rev. D93 (2016) no.7, 075031; arXiv:1601.01712, accepted by Phys. Rev. Lett.

SM $\gamma\gamma$ exclusive production





Select photon induced processes: stay tuned, it might be one the most important discoveries in physics if confirmed by Summer/Autumn!


LHC is now in operation, stay tuned…
Thank you !