Intermediate and High Energy Physics

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Joy of studying physics

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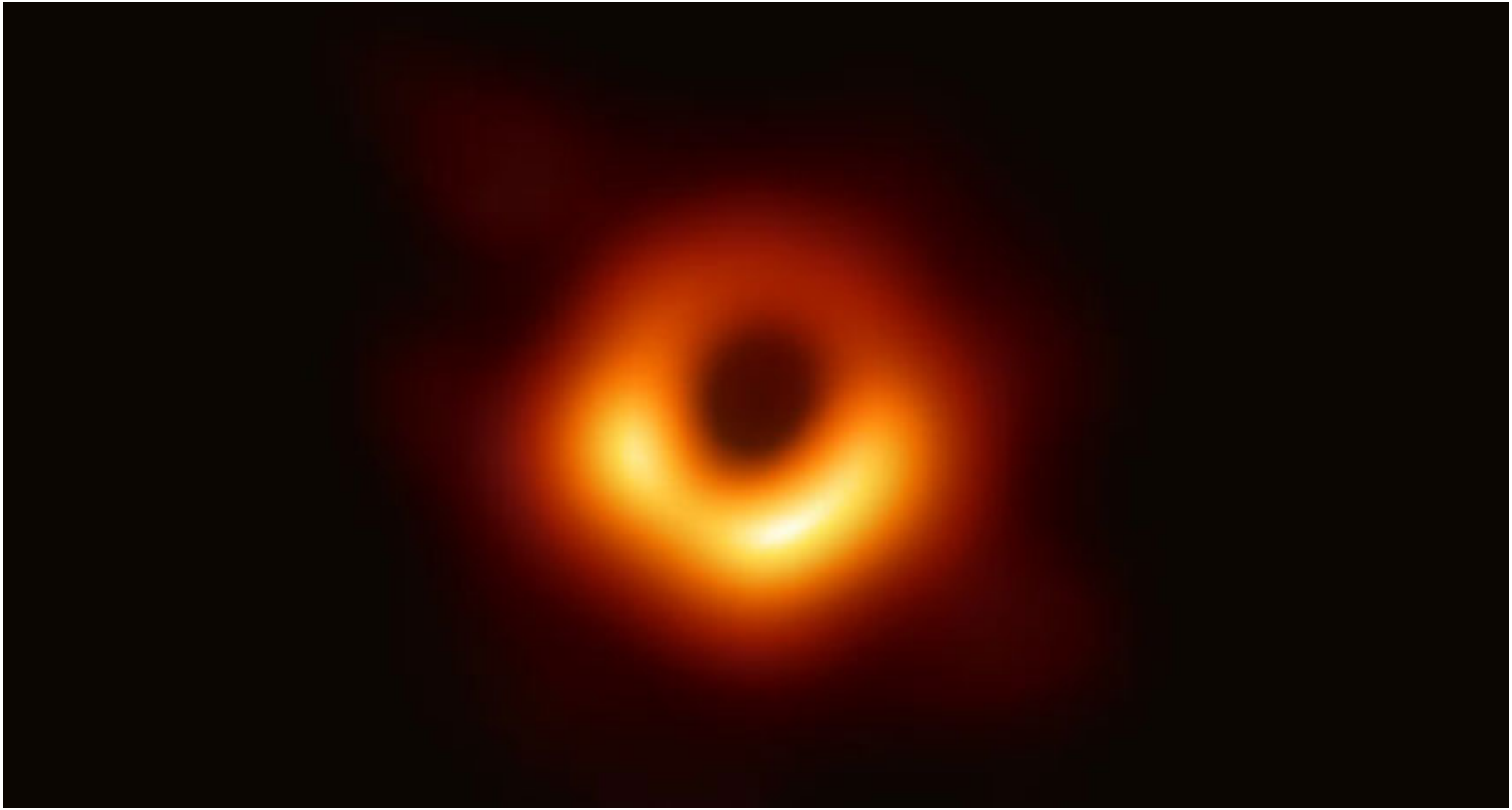
Beautiful results!



▸ ScienceNews: The first picture of a black hole opens a new era of astrophysics

Overture

1. Introduction
   - Define some terms
2. How Good Is the Standard Model?
   - Intermediate Energy Regime: Lepton Universality
   - TREK/E36 Experiment
3. Where is the Mass of Universe?
   - What is the Proton?
4. Closing

Fundamental particles, what are they?

Defining some terms...

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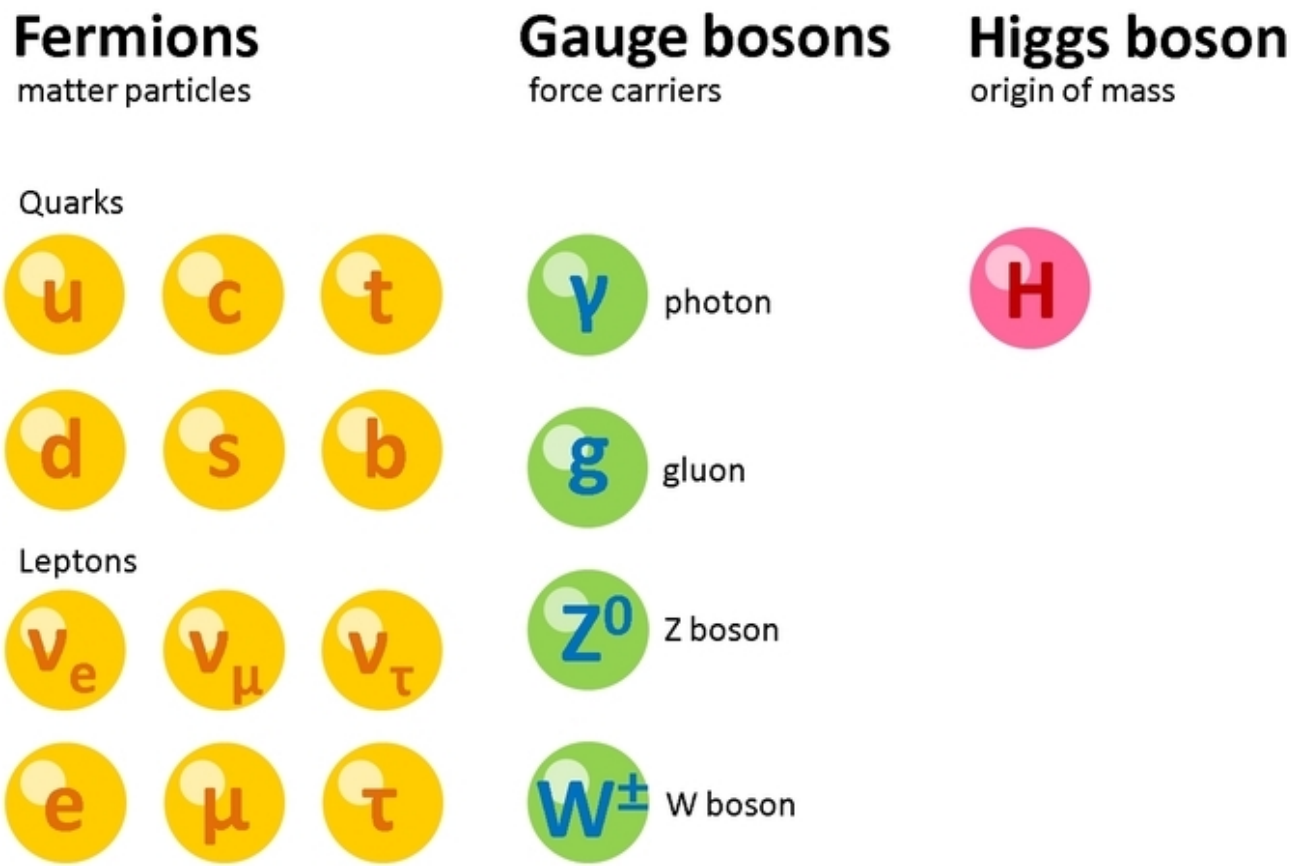
Defining some terms...



A rose is a rose, is a rose... by Gertrude Stein

Big Question Number 1: Just How Good is the SM?

- Lepton universality is a staple of the SM
- Leptons are distingushiable only through their masses
- Ergo: leptons have identical coupling constants
- Violation of lepton flavor universality is clear evidence of BSM Physics

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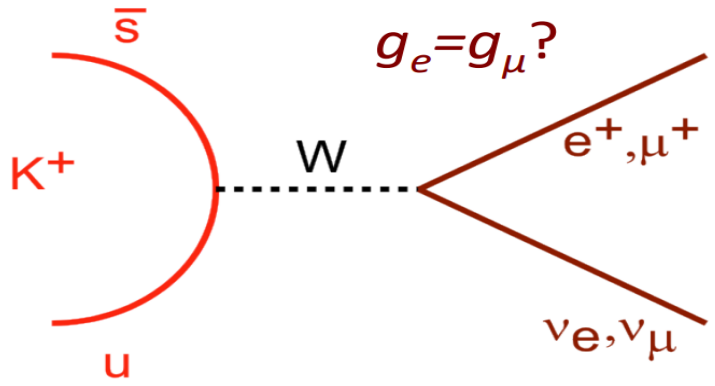
This is a good place to search for New Physics

Lepton Universality: 2-body decay of K^+

- LHCb, Belle & BaBar observed lepton non-universality at 3σ level
- E36 will test lepton universality with stopped K^+

LHCb (Phys. Rev. Lett. 113)

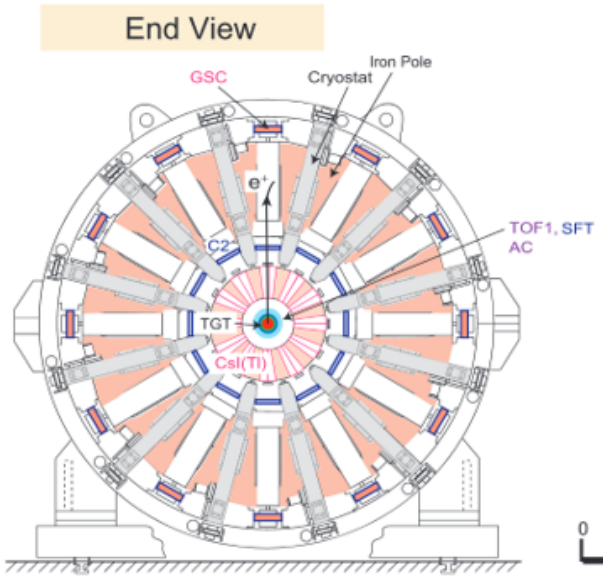


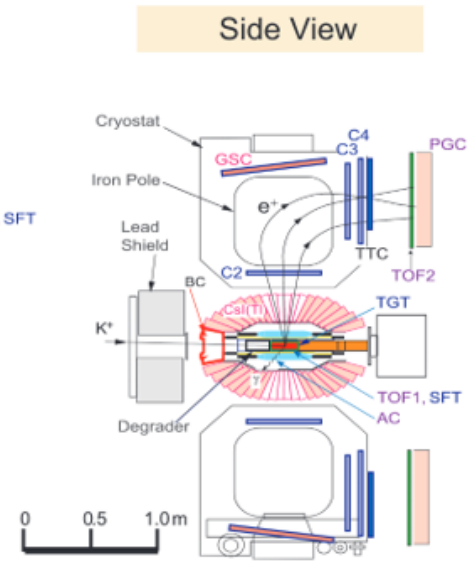
Decay width ratio of electronic (K_{e2}) and muonic ($K_{\mu 2}$) decay modes

$$R_K^{SM} = \frac{\Gamma(K^+ \to e^+\nu)}{\Gamma(K^+ \to \mu^+\nu)} = \frac{m_e^2}{m_\mu^2}\left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2}\right)^2 (1+\delta_r)$$

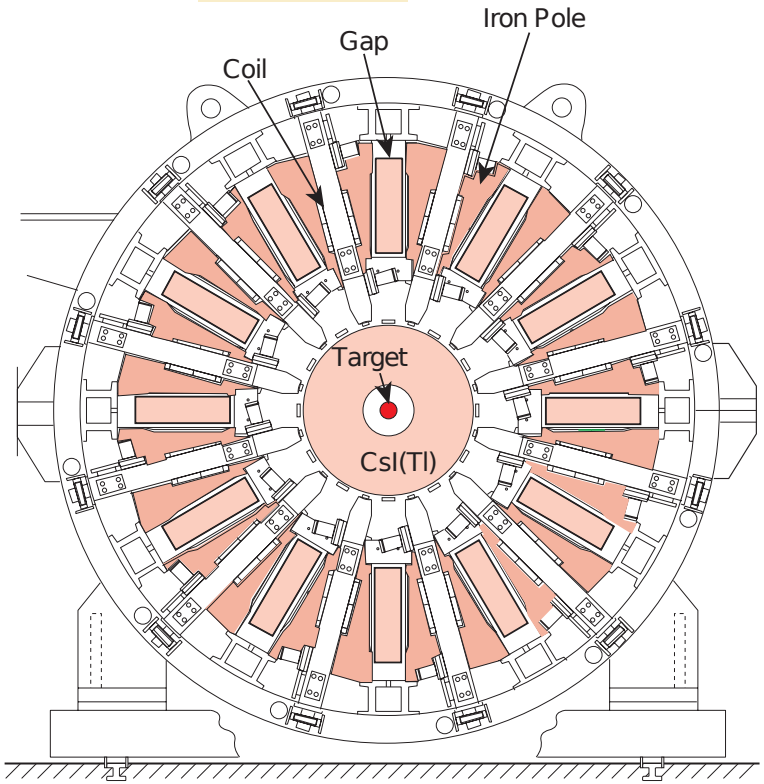
- Hadronic uncertainties cancel
- Strong *helicity* suppression of electronic channel enhances sensitivity to effects beyond SM
- SM prediction is highly precise: $R_K^{SM} = (2.477 \pm 0.001) \times 10^{-5}$

This is good! Now what?

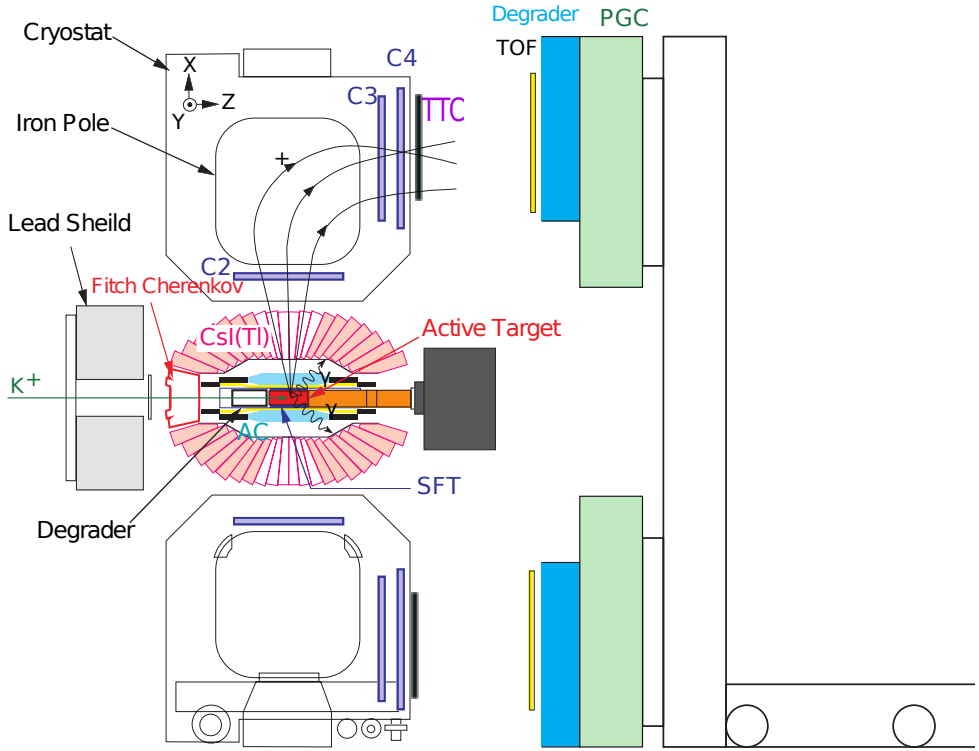

End View
GSC
Cryostat
Iron Pole
e+
C2
TOF1, SFT
AC
TGT
CsI(Tl)

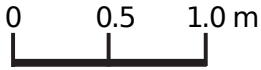

Side View
Cryostat
C4
C3
PGC
GSC
Iron Pole
e+
Lead
Shield
TTC
C2
TOF2
BC
CsI(Tl)
TGT
K+
TOF1, SFT
AC
Degrader
0
0.5
1.0m

End view



Side view





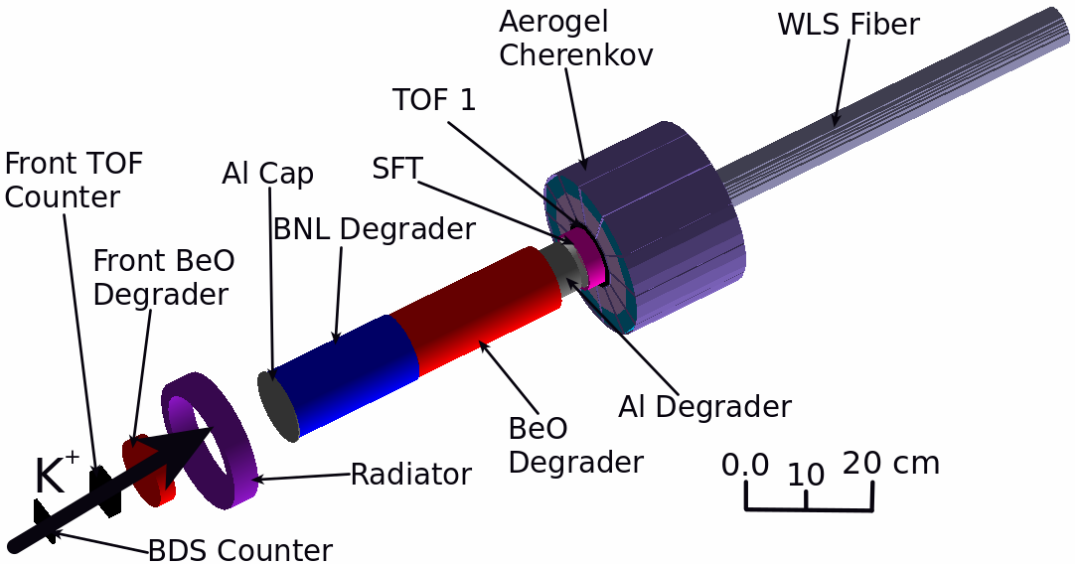
Stopped K^+ method
- K1.1BR beamline
- K^+ stopping target

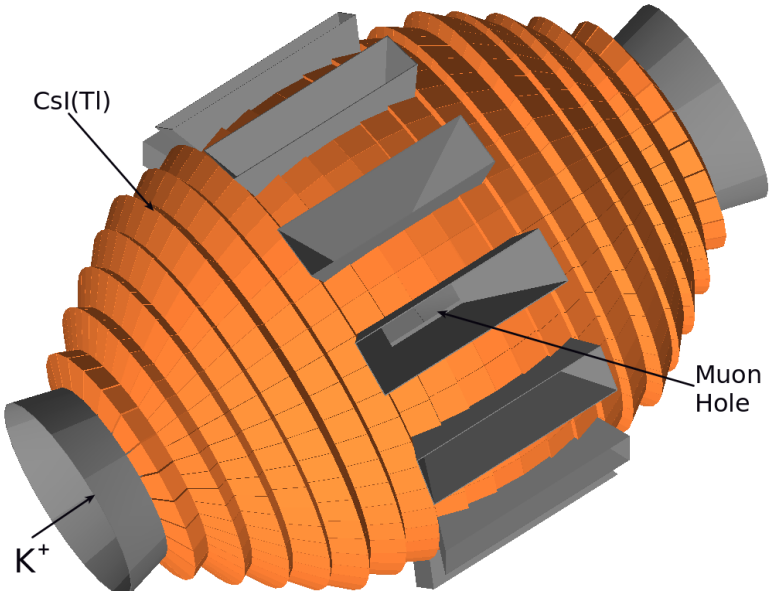
Momentum measurement
- MWPC (C2, C3, C4)
- Spiral fiber tracker (SFT)
- Thin trigger counter (TTC)

Particle ID
- TOF
- AC
- PGC

Gamma ray
- CsI(Tl)

Simulation Studies

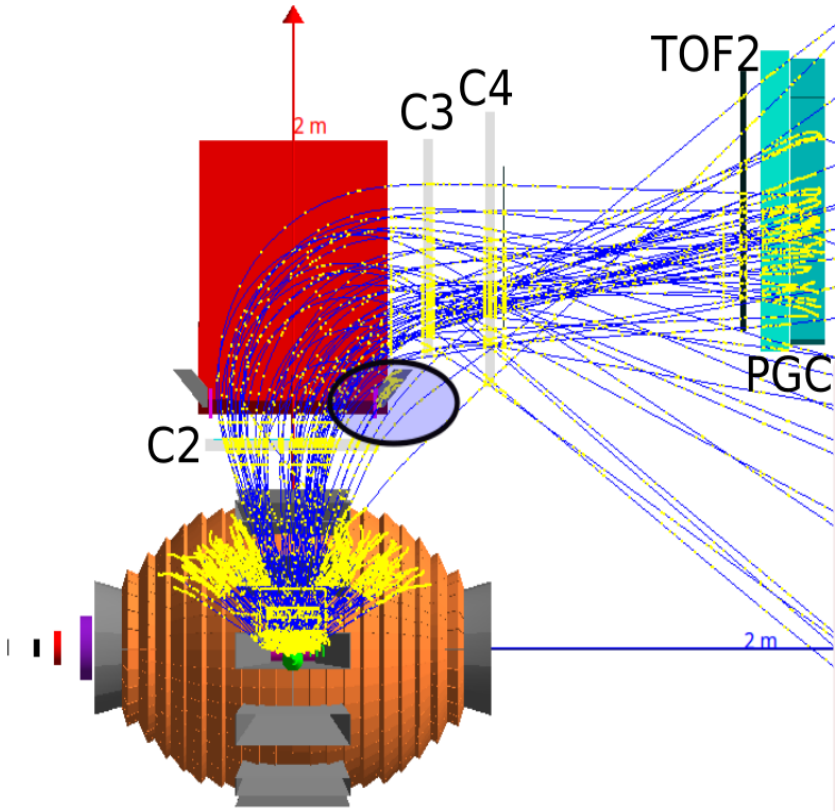




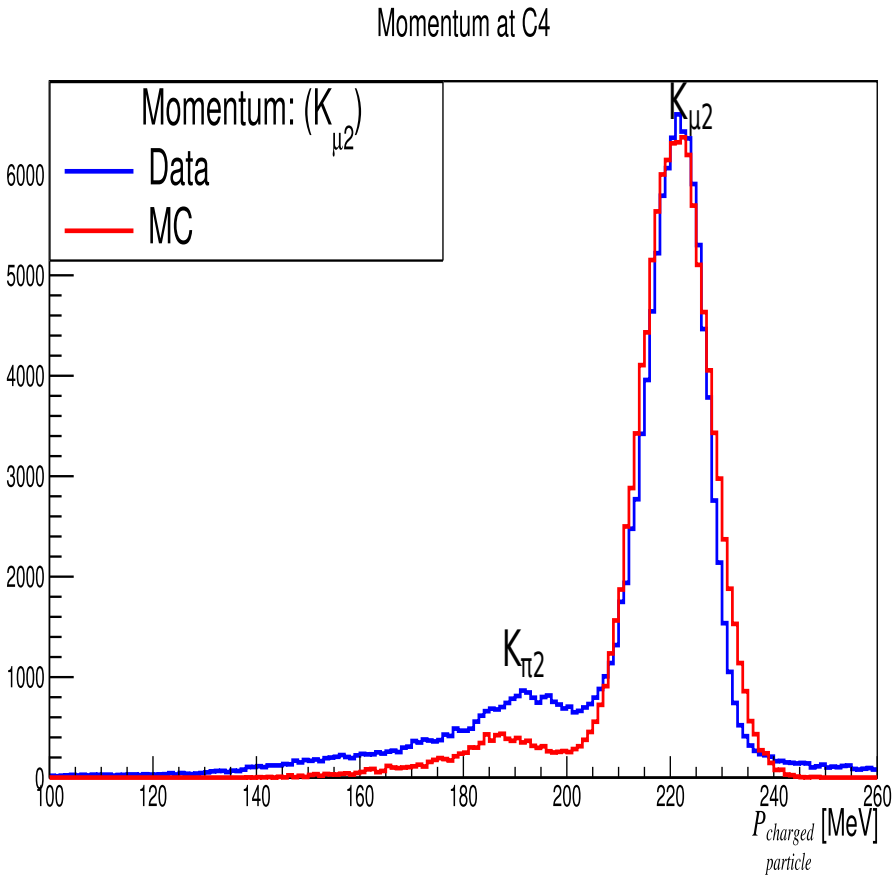
- Need a system of detectors
- Redundancy in particle identification (PID) detectors
- Active target useful for decay information

- Central Detector

Consistency Checks and Diagnostics



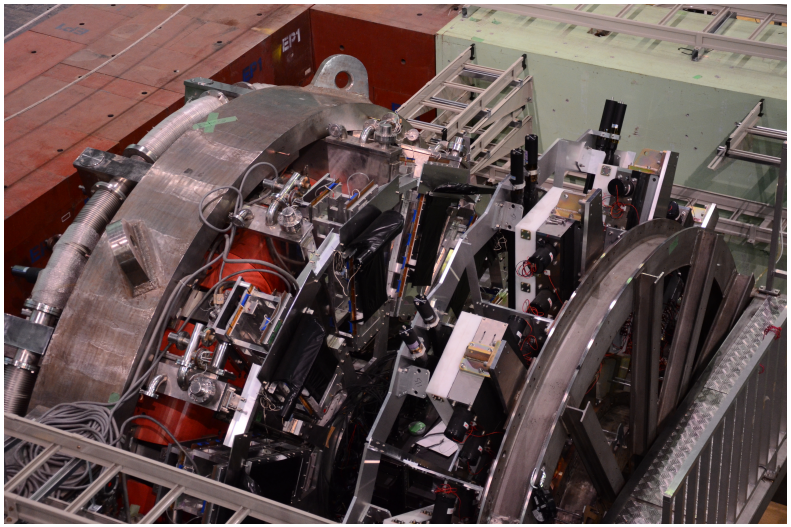
- Momentum distribution of $K_{\mu 2}$ and $K_{\pi 2}$ at C4
- E_{loss} and material budget well described
- Magnetic field integral is well described
- MC smeared with detector resolution

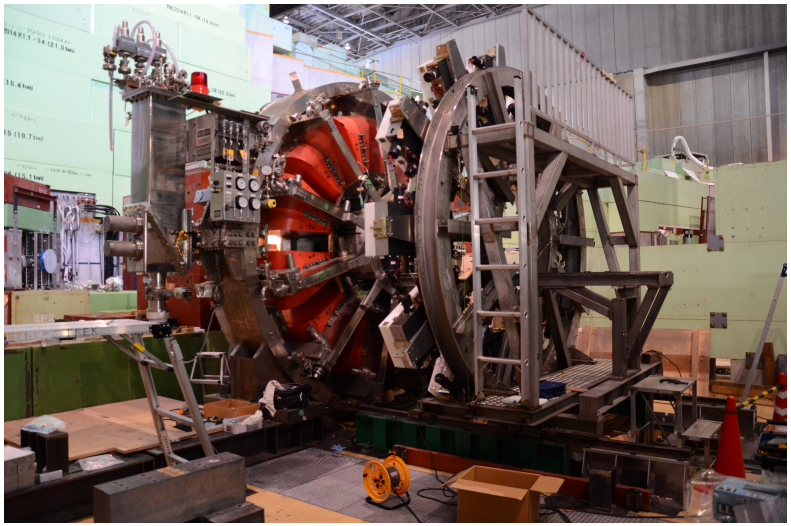


Terminology:

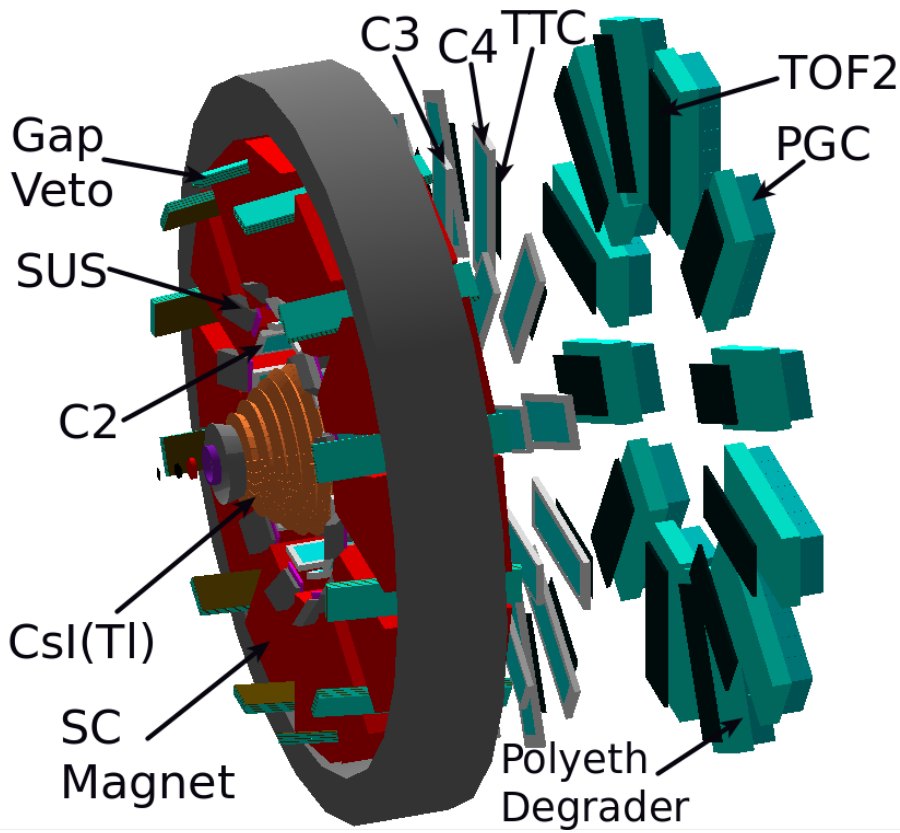
- $K_{\mu 2} : K^+ \rightarrow \mu^+ \nu$
- $K_{\pi 2} : K^+ \rightarrow \pi^+ \pi^0$

Putting it All Together...



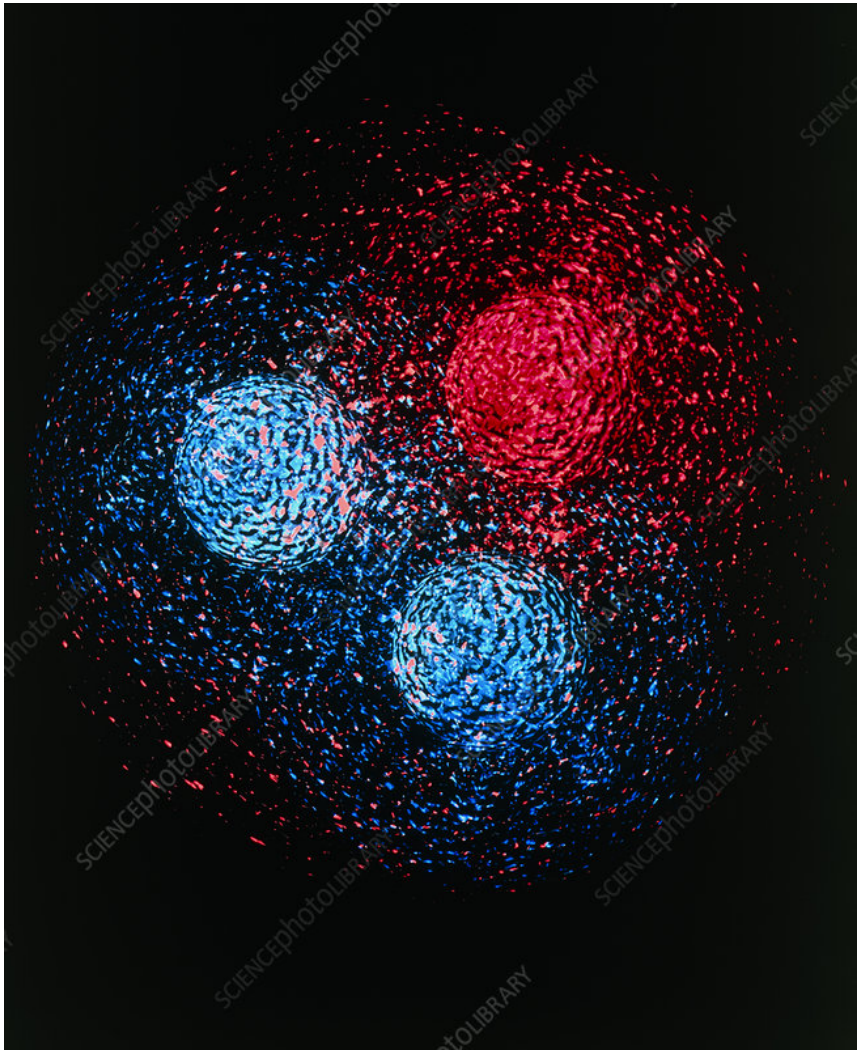


- Detector Assembly



- Geant4 E36 detector

What Exactly is the Proton?



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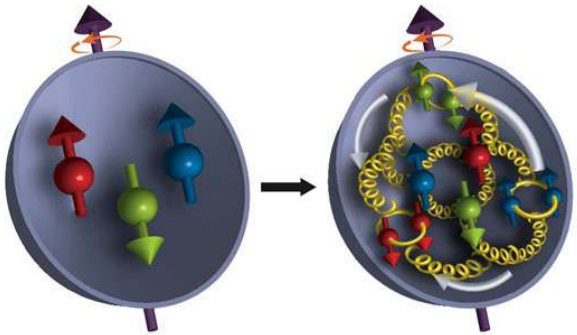
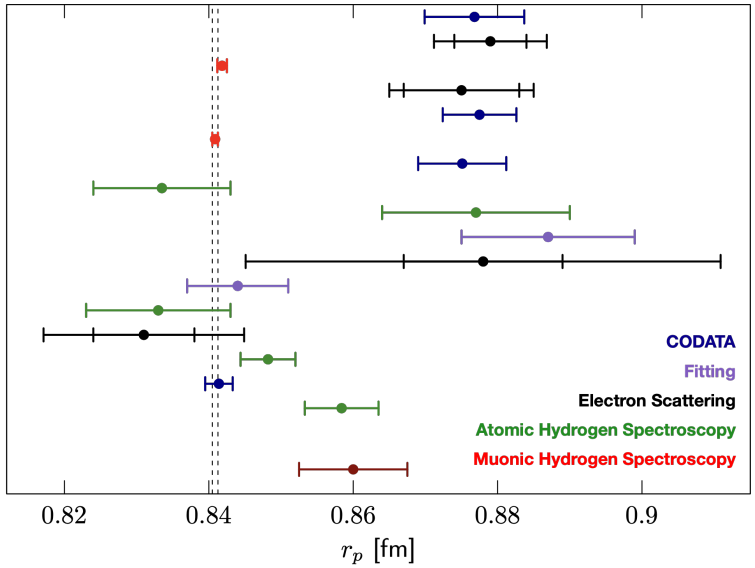




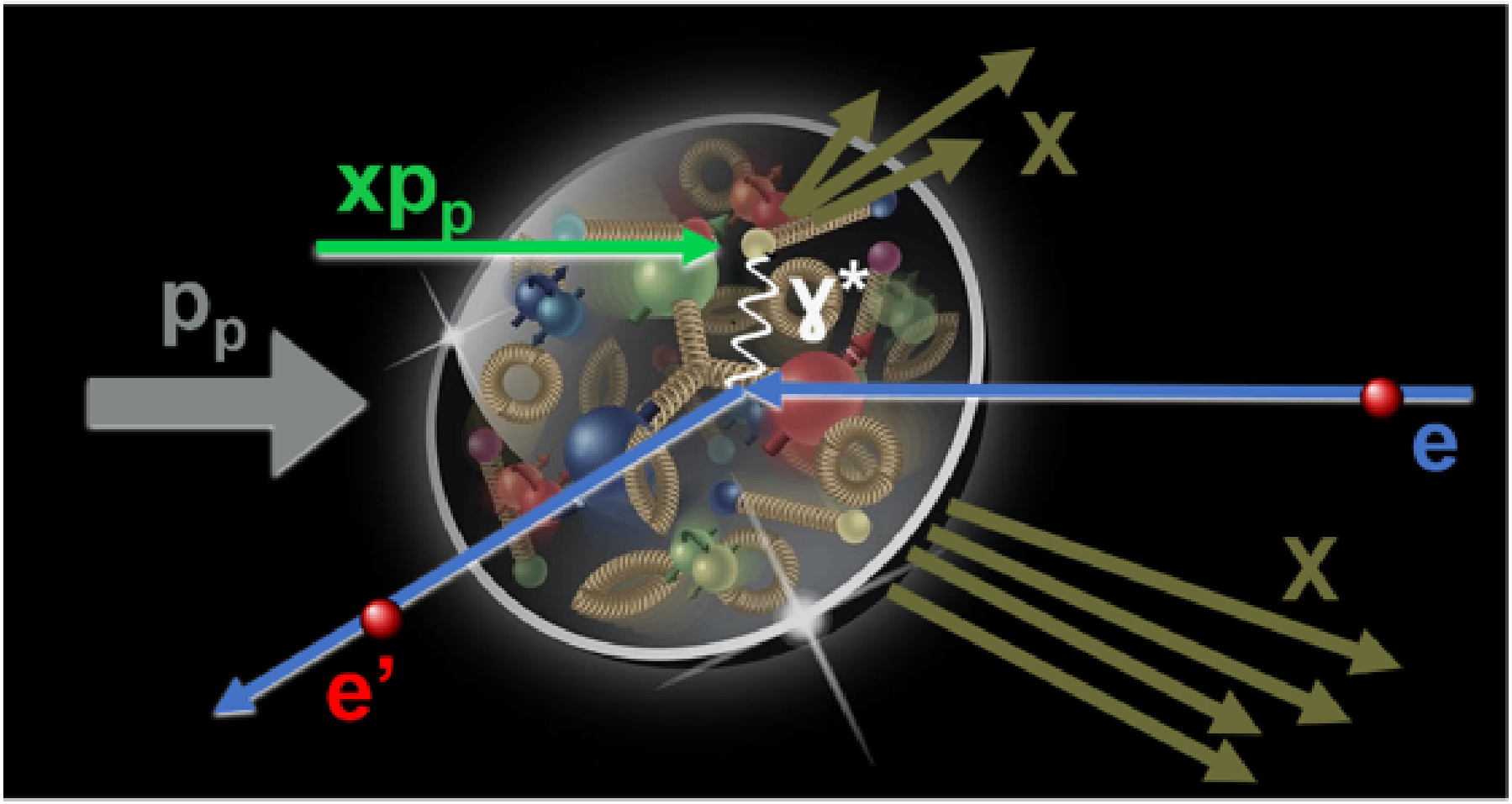
CODATA'06 (2008)
Bernauer (2010)
Pohl (2010)
Zhan (2011)
CODATA'10 (2012)
Antognini (2013)
CODATA'14 (2015)
Beyer (2017)
Fleurbaey (2018)
Sick (2018)
Mihovilović (2019/2021)
Alarćon (2019)
Bezginov (2019)
Xiong (2019)
Grinin (2020)
CODATA'18 (2021)
Brandt (2022)

MUSE (proj.)

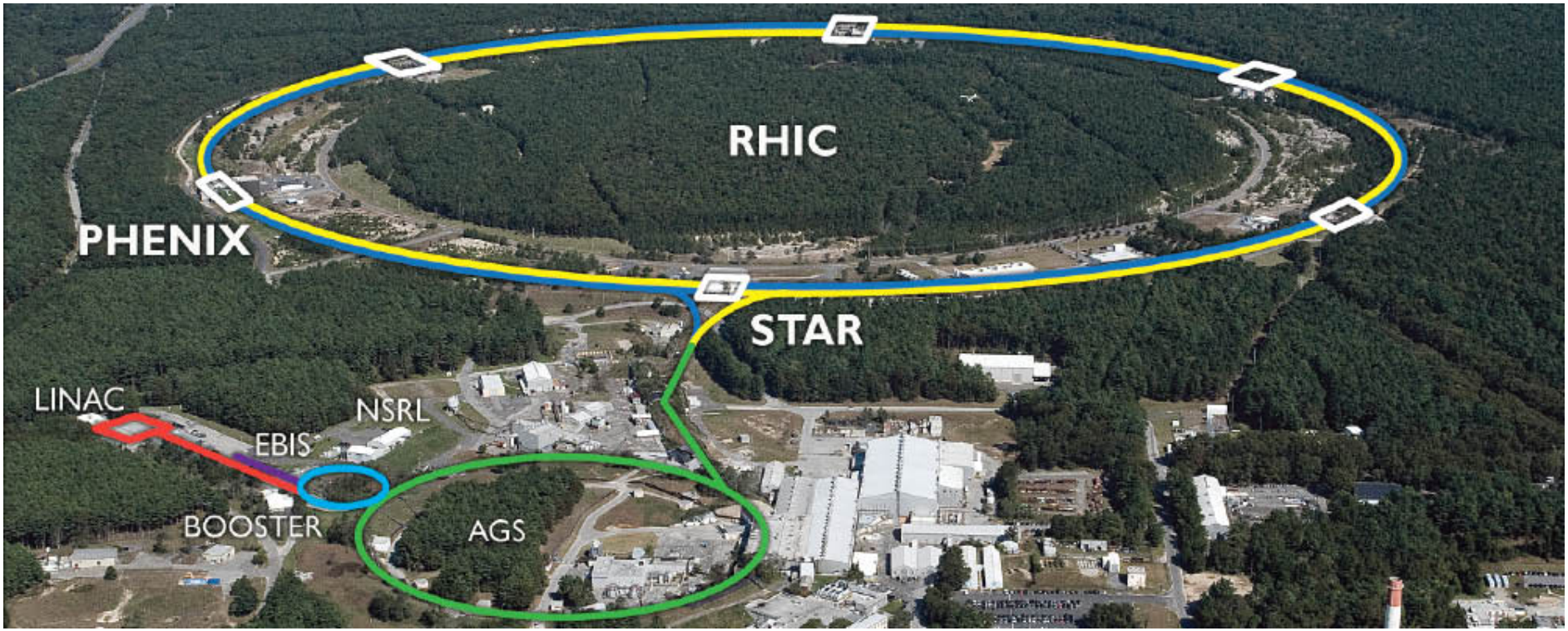
Proton Puzzles

- Proton spin crisis from 1987
- Proton radius puzzle
- Missing mass of the universe

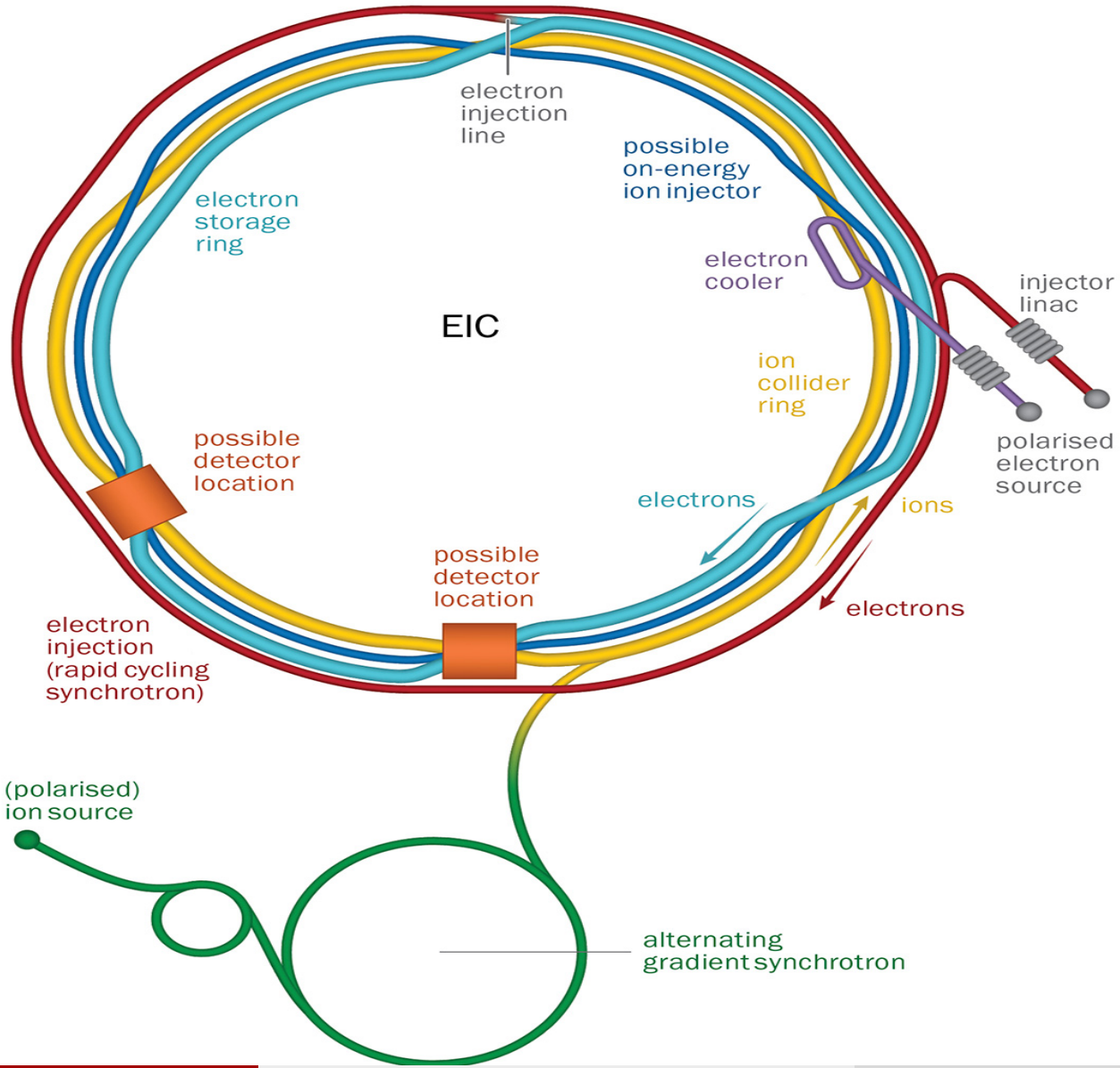
The Universe Within the Proton



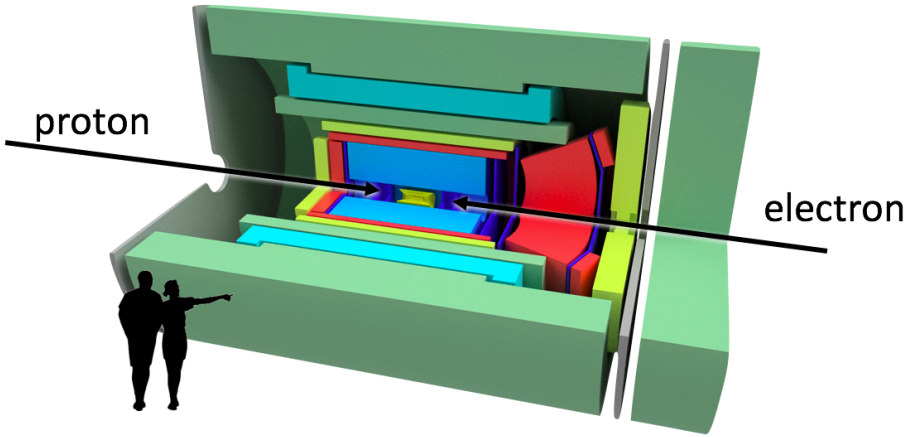
EIC Physics

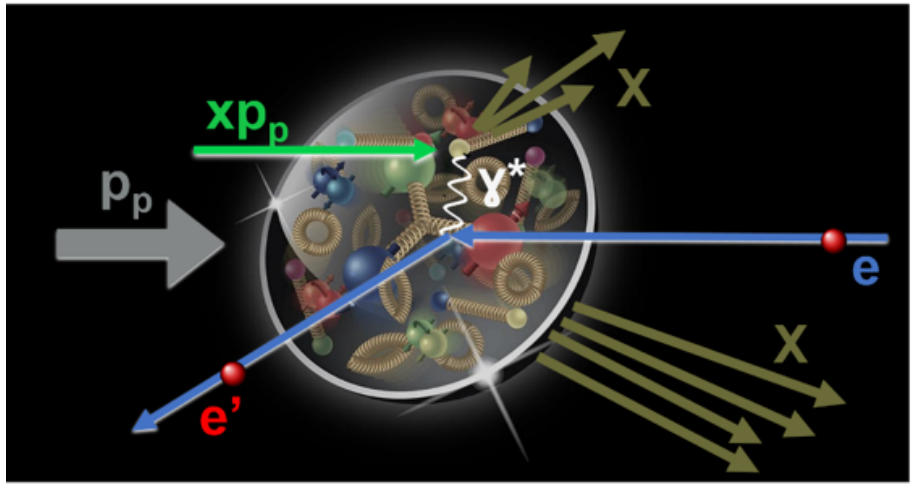


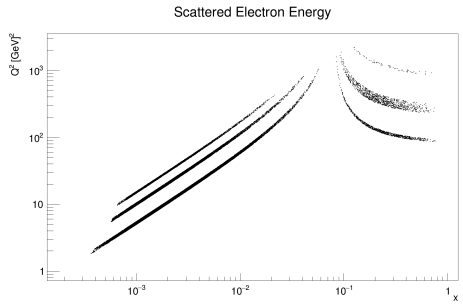
EIC Physics

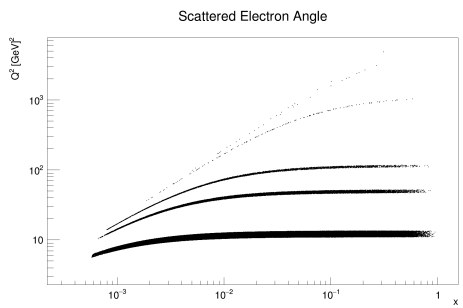

electron injection line
possible on-energy ion injector
electron storage ring
electron cooler
injector linac
EIC
ion collider ring
possible detector location
polarised electron source
electrons
ions
possible detector location
electrons
electron injection (rapid cycling synchrotron)
(polarised) ion source
alternating gradient synchrotron

Deep Inelastic Scattering: $e - p$





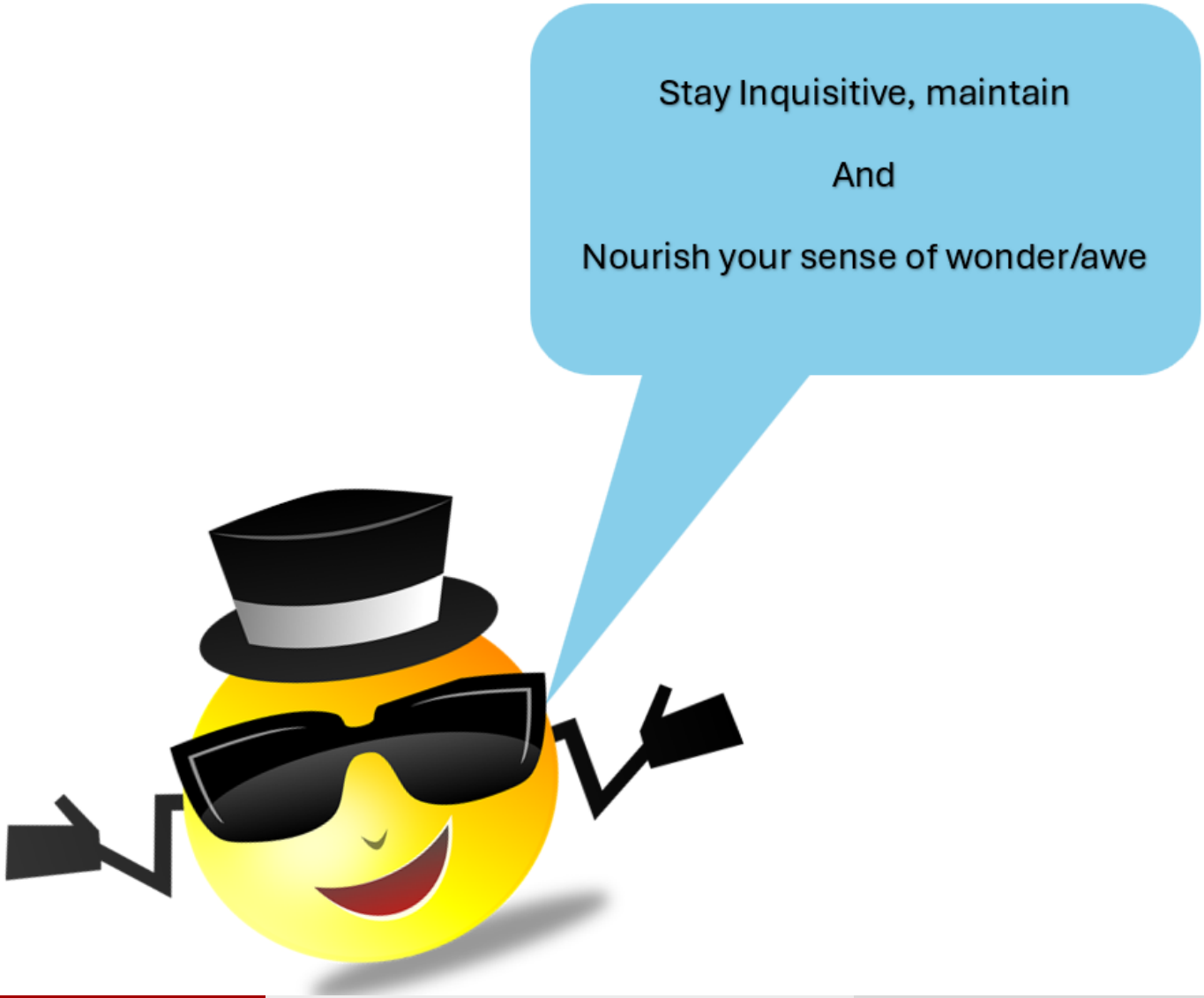




- Proton: 250. GeV/c
- Electron: 20. GeV/c
- Q^2: momentum transfer
- x: momentum fraction carried by parton (quarks/gluons)

- Extract kinematic plots from scatering
- Most e's maintain their direction

Re-cap


Stay Inquisitive, maintain
And
Nourish your sense of wonder/awe