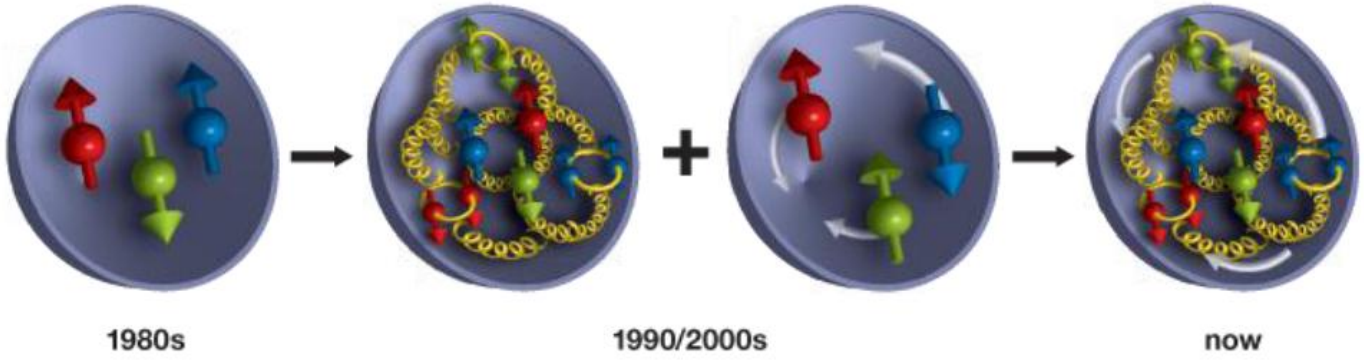
COMPASS and AMBER
Fixed-target Experiments to study QCD

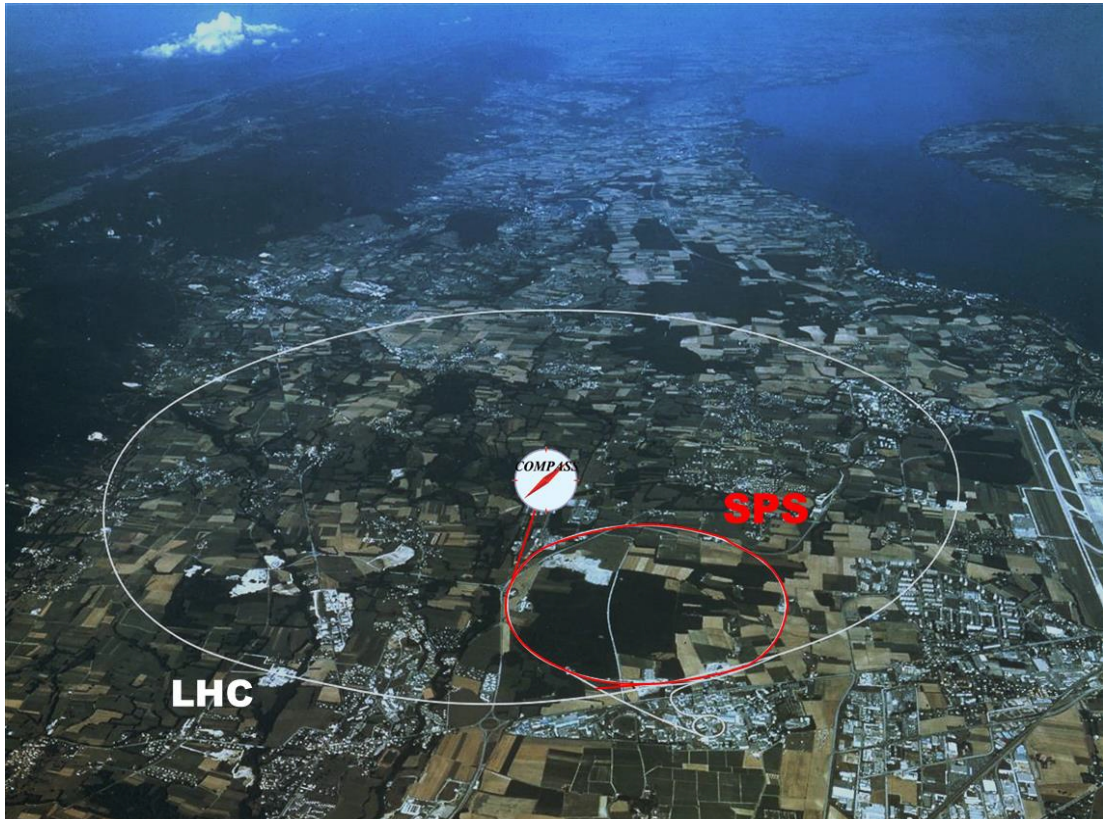
C. Quintans, LIP-Lisbon

7 February 2020, 5th Lisbon mini-school on Particle and Astroparticle Physics



Presently: COMPASS @ CERN

COmmon Muon and Proton Apparatus for Structure and Spectroscopy



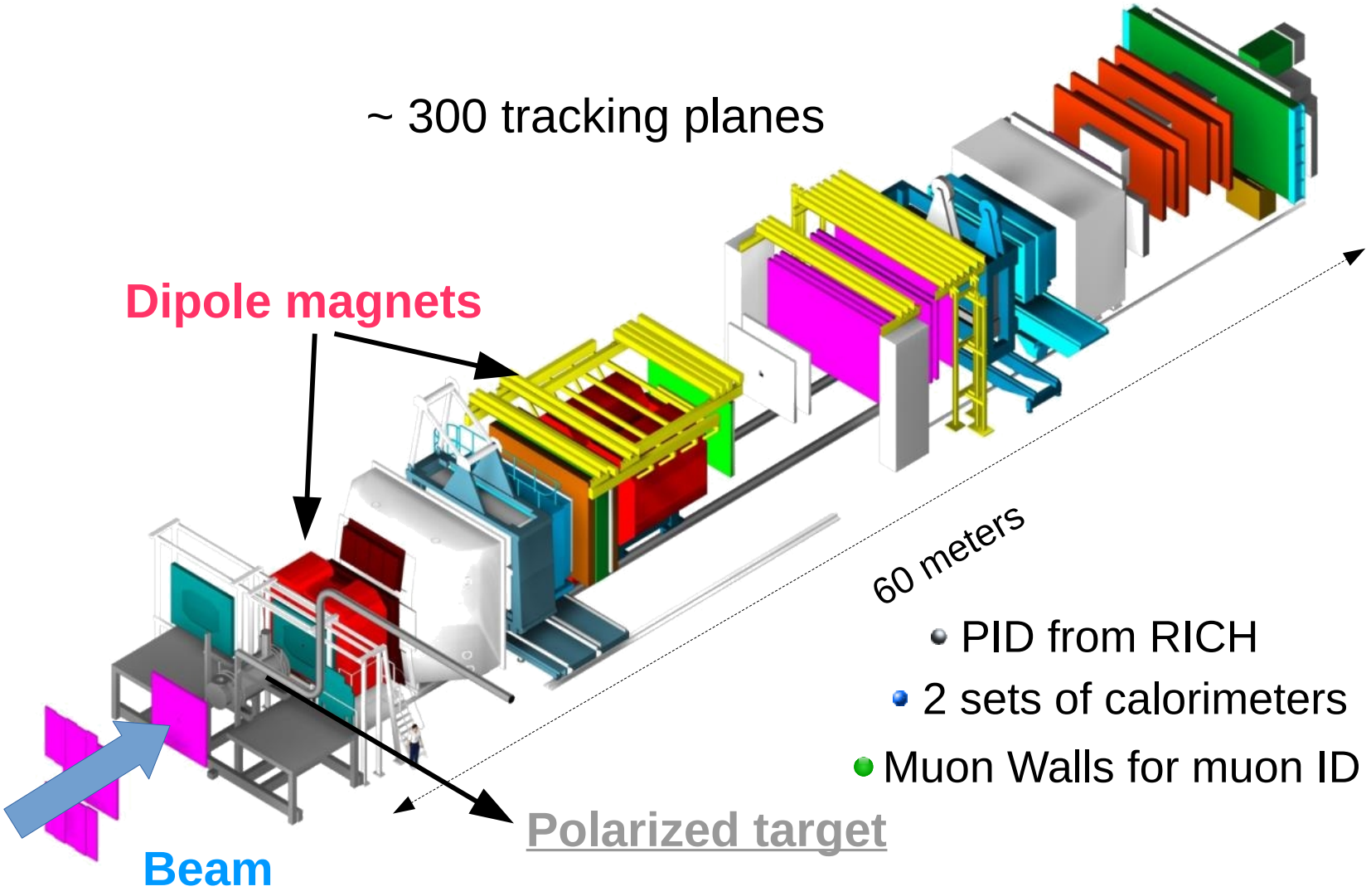
230 physicists from 12 countries

...including 2 portuguese groups:

- Aveiro (Instrumentation);
- LIP-Lisbon (Analysis & Detector Control).

LIP-Lisbon team

COMPASS experiment

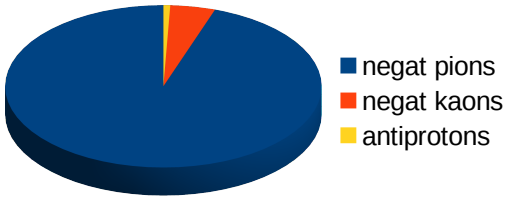


A multi-purpose beam line

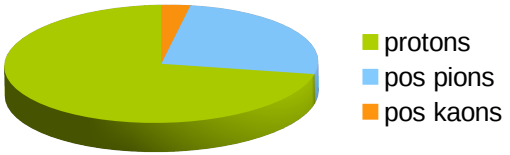
- Hadron beams (pos/neg)
- Muon beams (pos/neg)
- Beam energies
  from 80 to 280 GeV

World-unique beams!

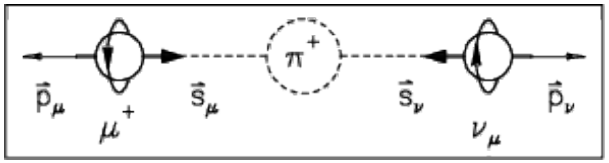
190 GeV Negative hadron beam



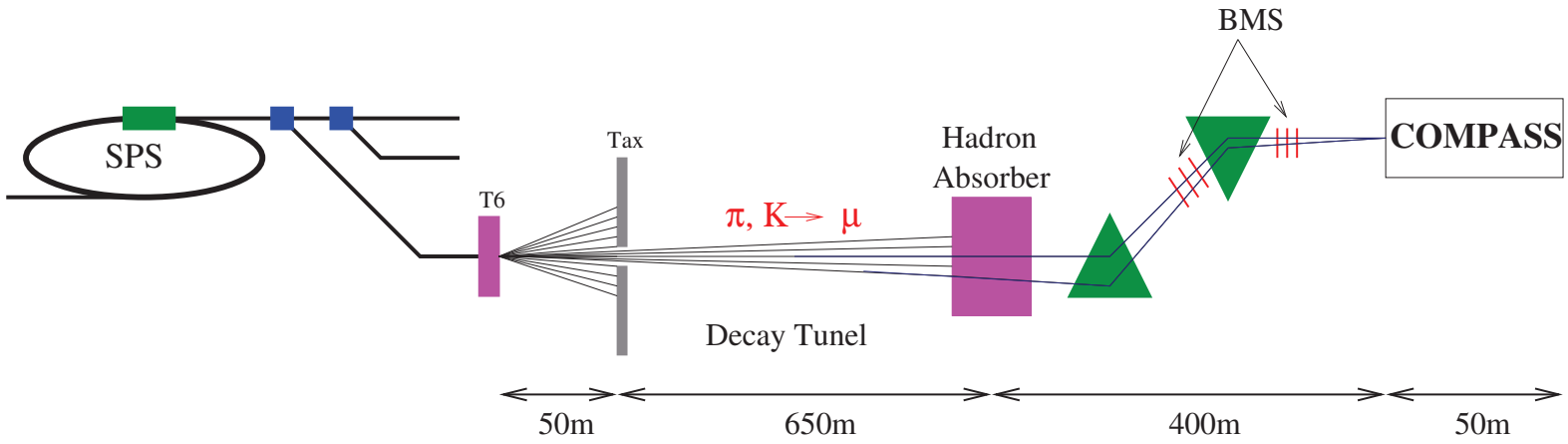
190 GeV Positive hadron beam



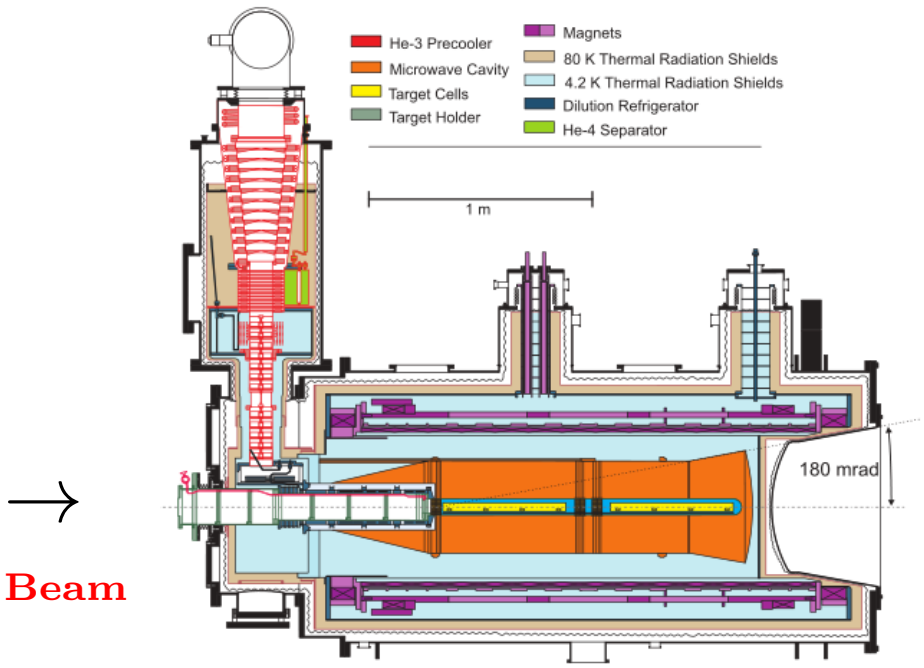
160/200 GeV muon beams



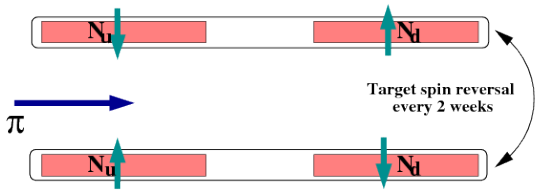
Muons from pion decays are **naturally polarised**



Polarized targets



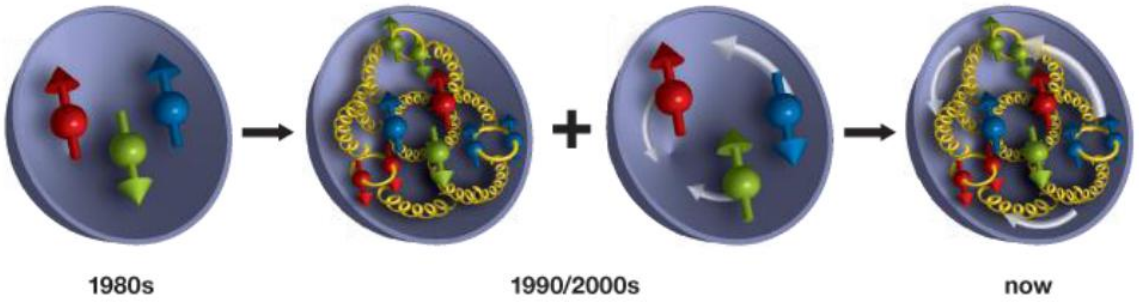
- NH_3: polarised protons; ^6LiD: polarised deuterons
- Spin flips forced by applied microwave
- 2.5 T superconducting solenoid field to align
- 60 mK temperature to freeze spin state
- Both transverse and longitudinal target polarization possible



With a polarized target, one can search for asymmetries in the products of given physics reactions – a direct method to study the spin structure of the nucleon.

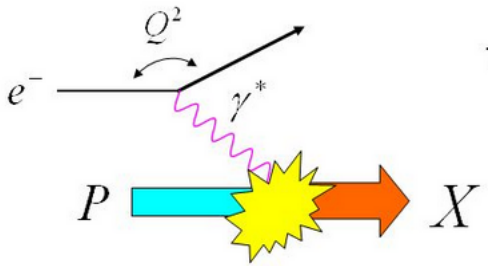
$$A^{\mu N} \propto \frac{N^{\Rightarrow} - N^{\Leftarrow}}{N^{\Rightarrow} + N^{\Leftarrow}}$$

COMPASS: Unveiling QCD misteries

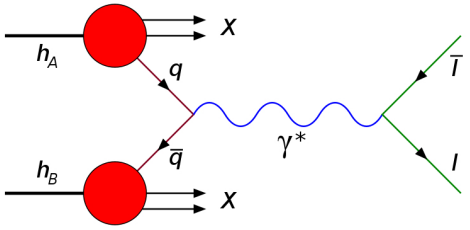


- The nucleon has a structure – quarks, gluons and their dynamics
- The nucleon has spin 1/2: how its contituents contribute to it?
- The nucleon mass is 10 times larger than the pion mass. Why?

Some favorites for probing the nucleon:

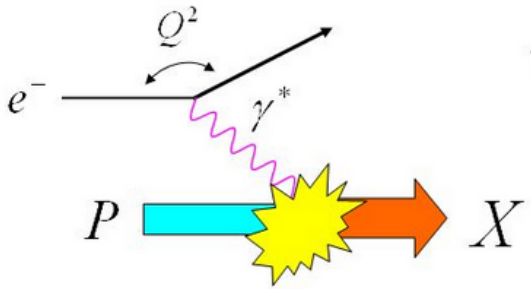


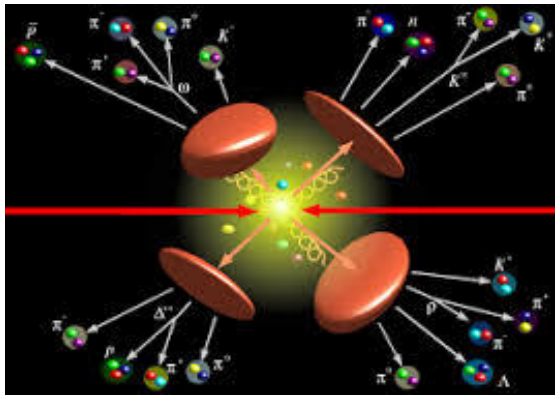
Deep Inelastic Scattering



Drell-Yan

Quarks fragmenting into hadrons





Fragmentation Function: probability that a **quark** i fragments into a **hadron** h carrying a fraction z of the parent's momentum.

In COMPASS we compare the amounts of charged kaons, pions and protons produced, to access these fragmentation functions.

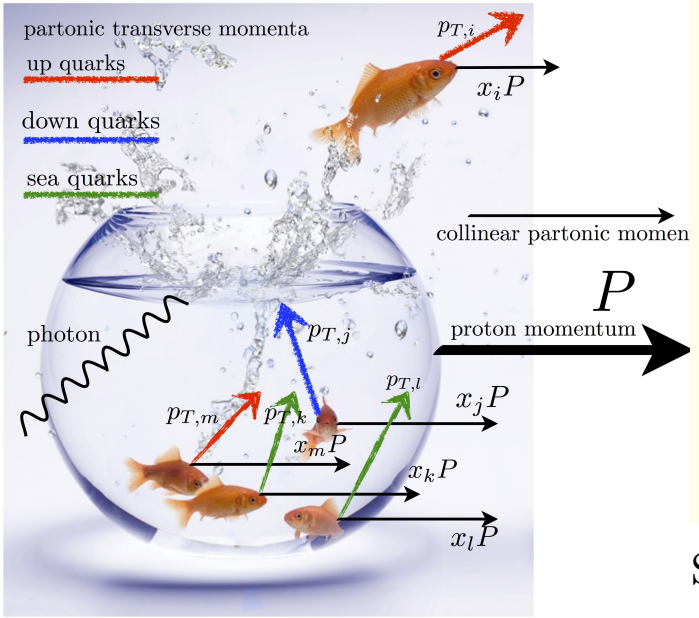
COMPASS data taken in 2016 and 2017 with $\mu^{\pm}$ beams on a liquid hydrogen target starting to be analysed.

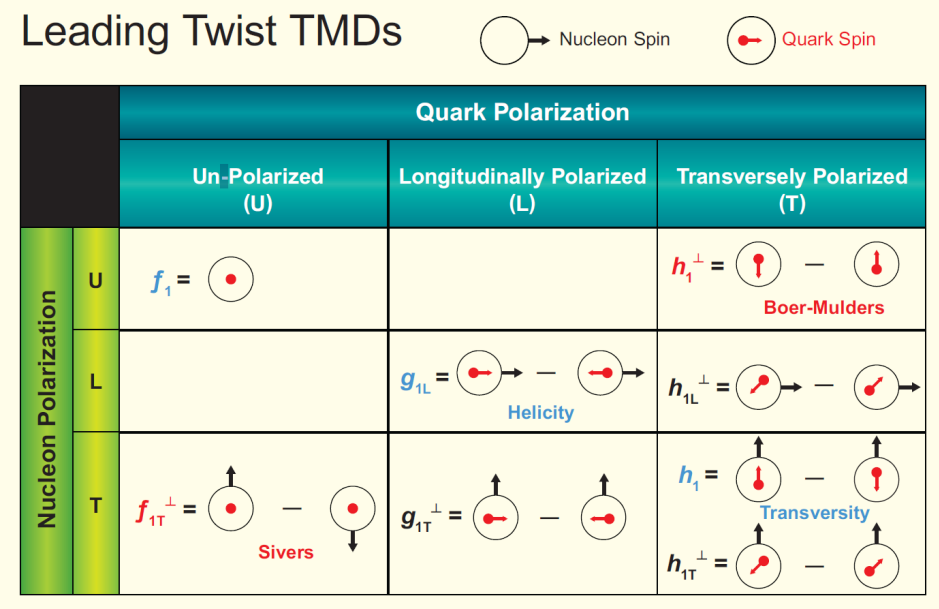
↪ Come and join this effort!

Spin and transverse momentum of quarks in the proton

Parton distribution functions give the probability to find a **quark** i inside a **nucleon** N carrying a fraction x of its parent's momentum.

But quarks and gluons might not be collinear with the proton: a **transverse momentum** k_T

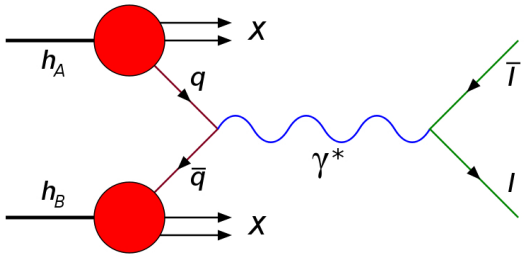


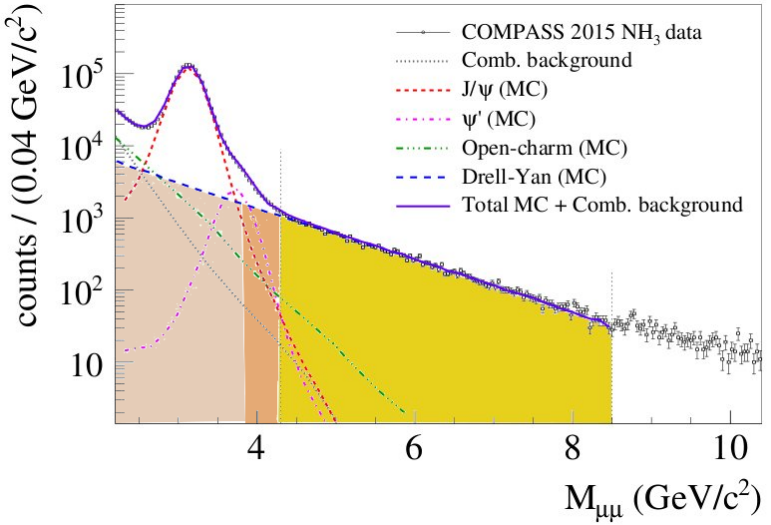


Study the correlations between spin of the nucleon, spin of its quarks, and transverse momentum of both.

TMDs: the dynamics inside the proton

Drell-Yan: $q\bar{q} \rightarrow \gamma^* \rightarrow \mu^+\mu^-$



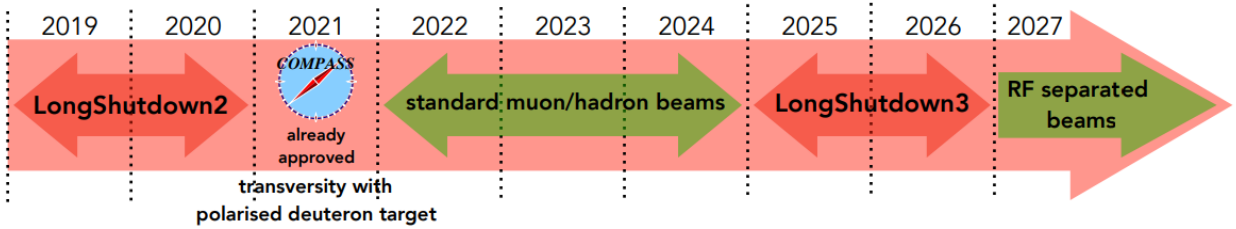


- First-ever **polarized Drell-Yan** experiment in the world!
- Access TMD PDFs of the proton
- Learn also how quarks distributions inside the pion behave differently from those inside the proton
- **COMPASS data taken in 2015 and 2018** now being analysed

↪ Lots of new data, come join this effort!

Future: AMBER @ CERN

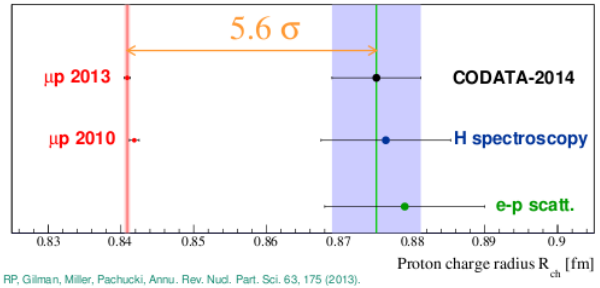
AMBER: new project at CERN extending COMPASS physics in new directions



Apparatus for
Meson and
Baryon
Experimental
Research

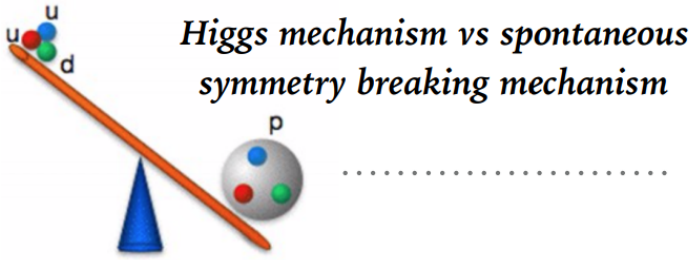
Among other topics, two important "mysteries" are to be addressed:

proton charge radius



...from muon-proton elastic scattering

emergence of hadron masses



...from pion and kaon induced Drell-Yan

Opportunities at COMPASS and AMBER

A young motivated team awaits you, with interesting Masters and PhD topics:

- Hadron multiplicities aiming at fragmentation function studies
- Drell-Yan process for parton distribution function studies of proton and pion
- Studies of hidden charm production mechanisms
- A new experiment on the way: feasibility and physics studies
- Use of most up-to-date data analysis techniques (e.g. machine learning algorithms)

- **Experiments where you can actually make a difference!**

LIP group: http://www.lip.pt/compass

COMPASS: http://wwwcompass.cern.ch

AMBER: https://nqf-m2.web.cern.ch