COMPASS
Status and Future

Jan Friedrich
TU München

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KHuK Bad Honnef / zoom

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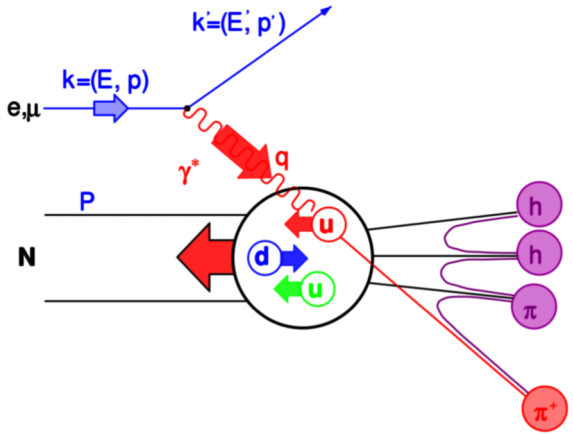
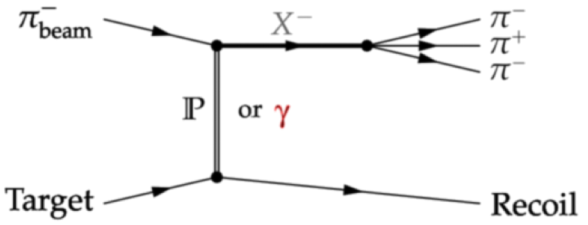
COMPASS: An apparatus optimized to resolve the quark-gluon structure of matter

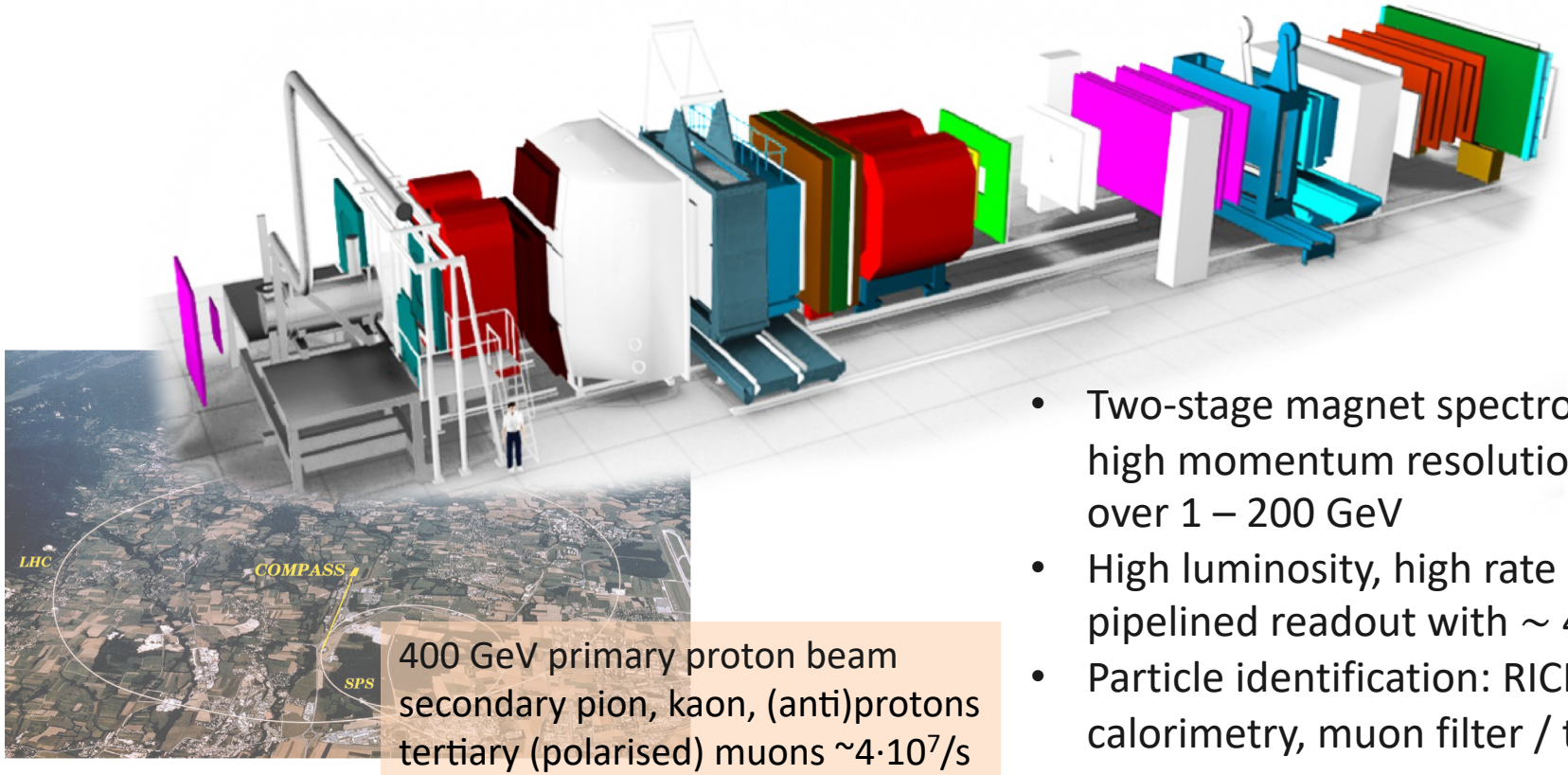
- Quarks and gluons form bound states ~10^{-15} m
  hadrons: baryons (fermionic) and mesons (bosonic)
  quarks flavours: light u, d, s (heavy: c, b ,t)
- Resolve such structures: $Q^2 > 1$ GeV^2
  - well-understood probe: muon beam (or electrons)
  - broad kinematic range using a high-energy beam
  - study the dynamics in deep-inelastic processes
  - polarised beam/target→ spin degrees of freedom
- Measure the light hadron resonance spectrum
  - use hadron beams: pions, kaons, (anti-)protons
  - study their excitations in soft scattering processes
  - observe the detailed decay kinematics to reveal resonance properties: mass, width, spin, parity





COMPASS

COmmon Muon Proton Apparatus for Structure and Spectroscopy



400 GeV primary proton beam
secondary pion, kaon, (anti)protons
tertiary (polarised) muons ~$4 \cdot 10^7$/s

- Two-stage magnet spectrometer: high momentum resolution ~ 10^{-3} over 1 – 200 GeV
- High luminosity, high rate capability: pipelined readout with ~ 40kHz rate
- Particle identification: RICH, EM/Had calorimetry, muon filter / trigger

- Collaboration of ~ 230 members
- 22 institutes: Prague, Saclay, Bonn, Freiburg, Mainz, München, Calcutta, Tel Aviv, Turin, Trieste, Yamagata, Warsaw, Lisbon, Dubna, Moscow, Tomsk, CERN, Taiwan, Illinois

Perturbative QCD
Semi-inclusive muon scattering at high Q^2

COMPASS I program

completion of transverse deuteron data taking in 2021/22

2002-04, 06: SIDIS with long. and trans. polarised deuteron target
2004, 08-09: Primakoff reactions and hadron spectroscopy
2007, 10-11: SIDIS with long. and trans. polarised proton target

Recently finished analysis: Correction to azimuthal hadron asymmetries due to exclusive vector-meson production

The COMPASS Collaboration / Nuclear Physics B 956 (2020) 115039

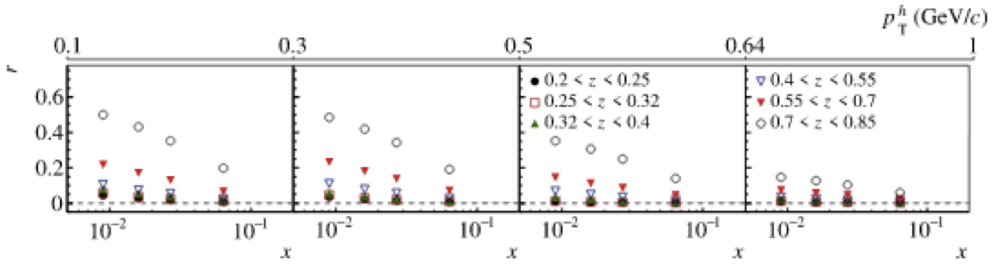
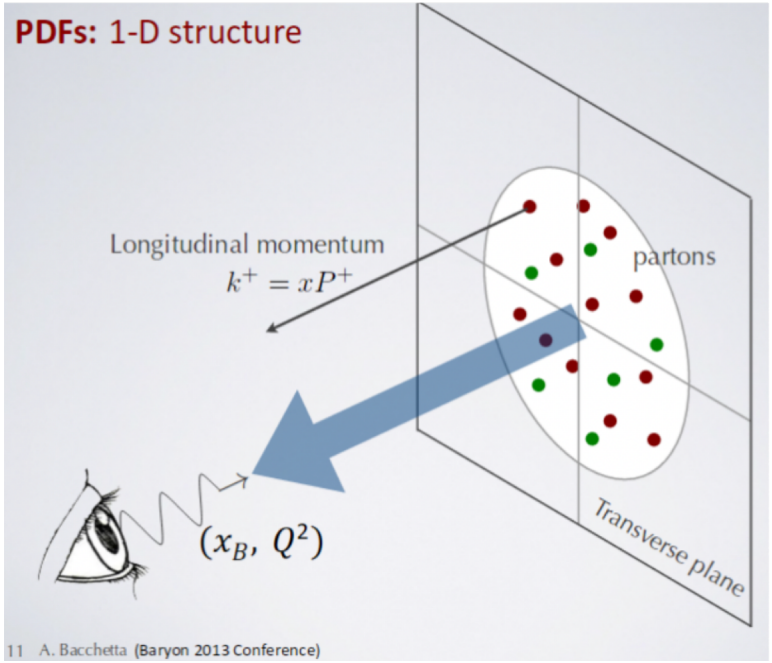


Fig. 4. Fraction r of exclusive-VM hadrons evaluated as function of x in the different z and p_T^h bins.

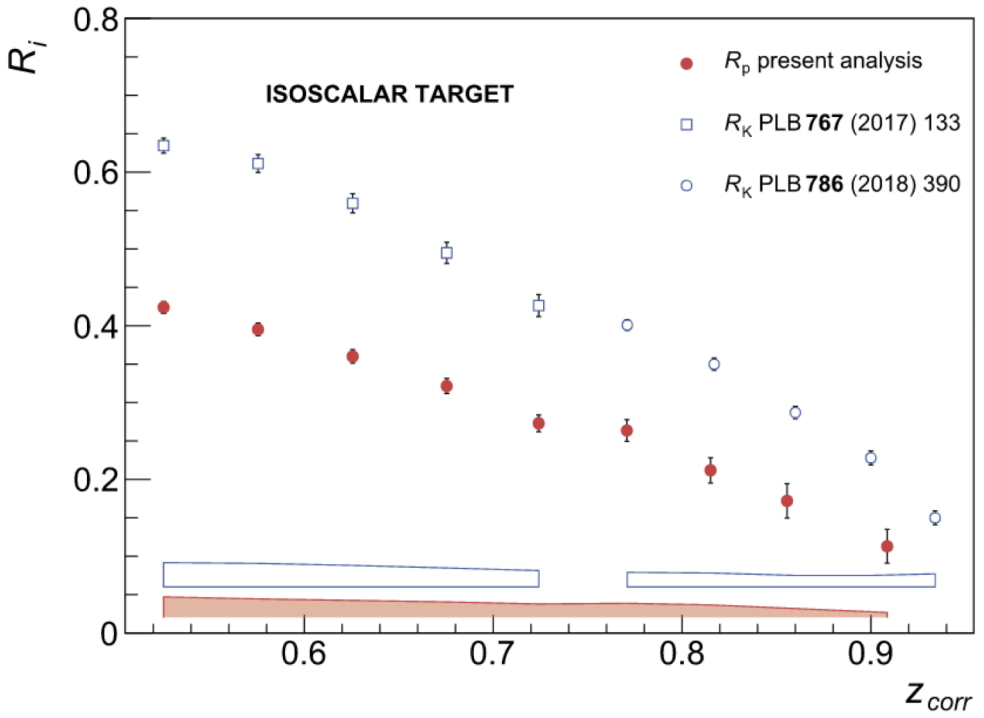


Perturbative QCD
Semi-inclusive muon scattering at high Q^2

$p/\bar{p}$ multiplicities: First antiproton-over-proton ratio determination in SIDIS from COMPASS 2006 data (refined RICH analysis)

$$R_p(x, Q^2, z) = \frac{dM^{\bar{p}}(x, Q^2, z)/dz}{dM^{p}(x, Q^2, z)/dz} = \frac{4.5(\bar{u}+\bar{d})D_{fav} + (5u+5d+2s+2\bar{s})D_{unf}}{4.5(u+d)D_{fav} + (5\bar{u}+5\bar{d}+2s+2\bar{s})D_{unf}}$$

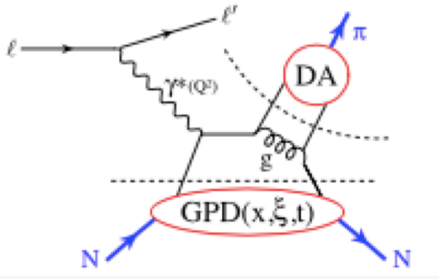
Physics Letters B 807 (2020) 135600

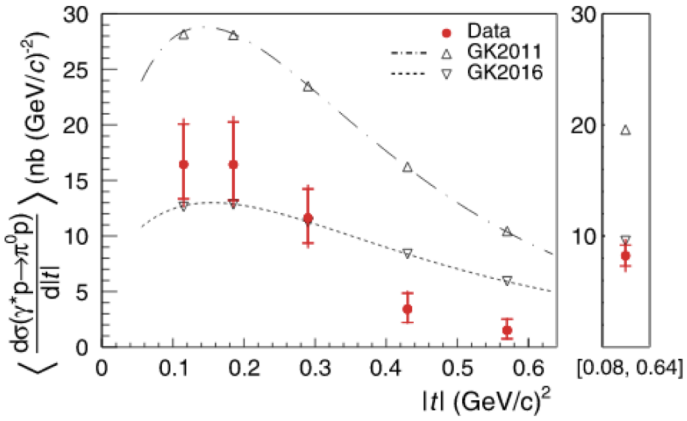


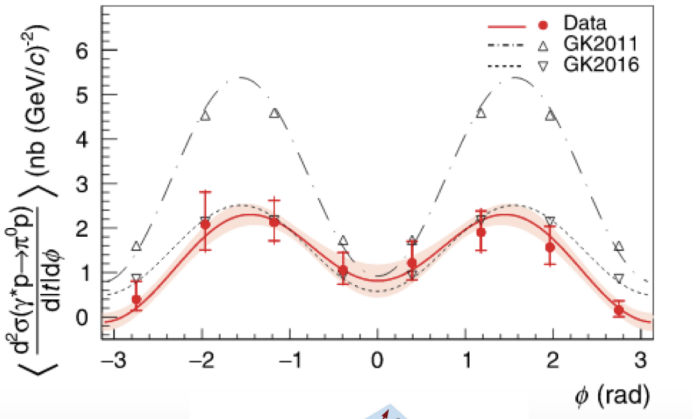
Perturbative QCD
Exclusive processes in high-Q^2 muon scattering

COMPASS II program

2012: Primakoff + HEMP / DVCS test run
2014: unpolarized Drell-Yan
2015: Drell-Yan with transversely polarised target
2016/17: HEMP / DVCS
2018: Drell-Yan with transversely polarised target

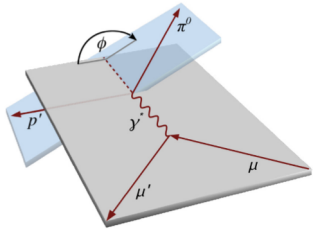






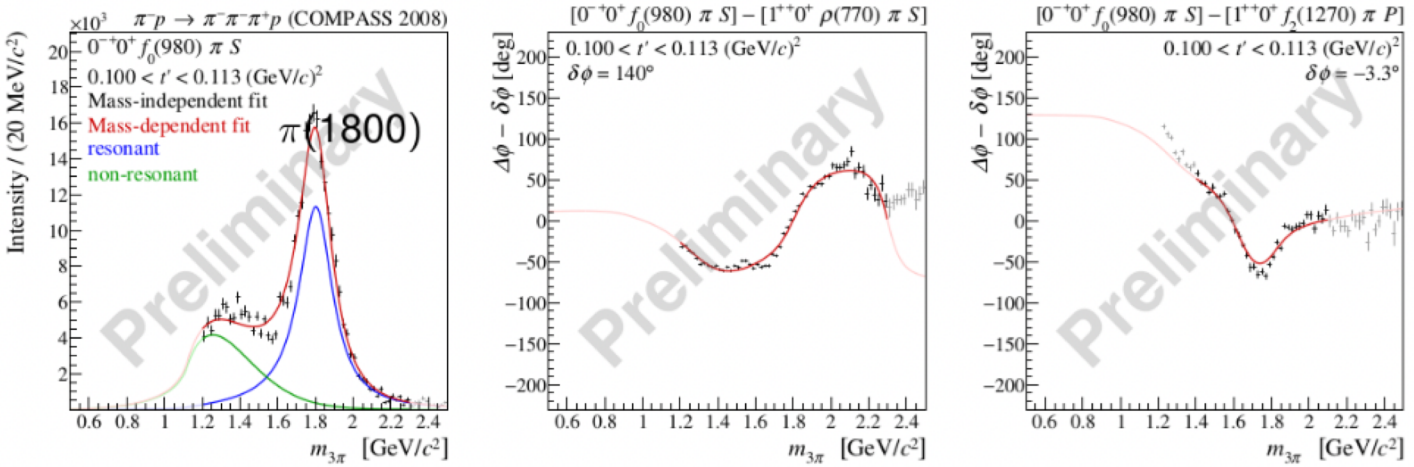
Physics Letters B 805 (2020) 135454

Measurement of the cross section for hard exclusive π^0 muoproduction on the proton



Light-meson spectroscopy

PRD 98, 092003 (2018): simultaneous fit of 11 resonances (14 waves) in diffractive 3π final states, one example:

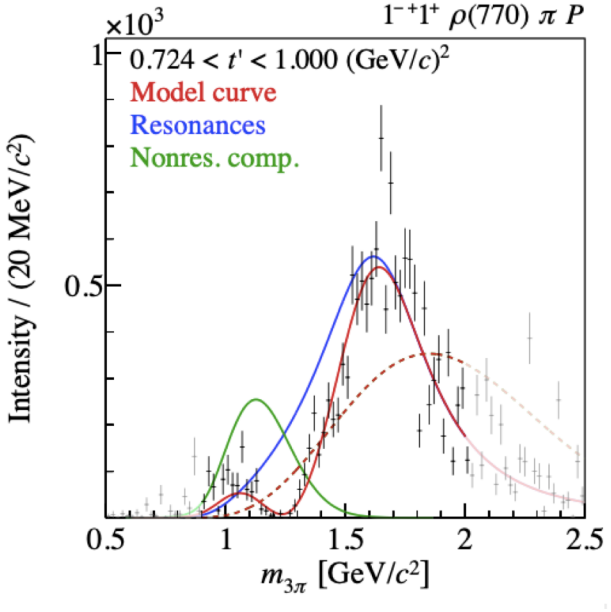


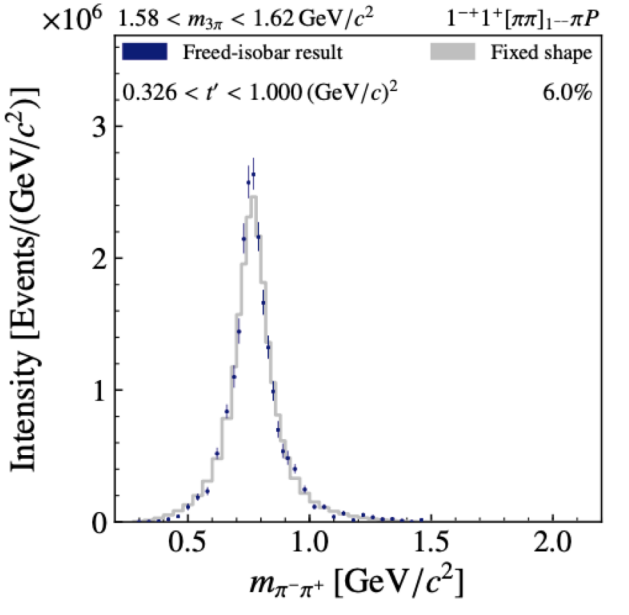
$$m_{\pi(1800)} = 1802.6^{+8}_{-3.5}\,\mathrm{MeV}/c^2\ ;\ \Gamma_{\pi(1800)} = 218^{+11}_{-6}\,\mathrm{MeV}/c^2$$

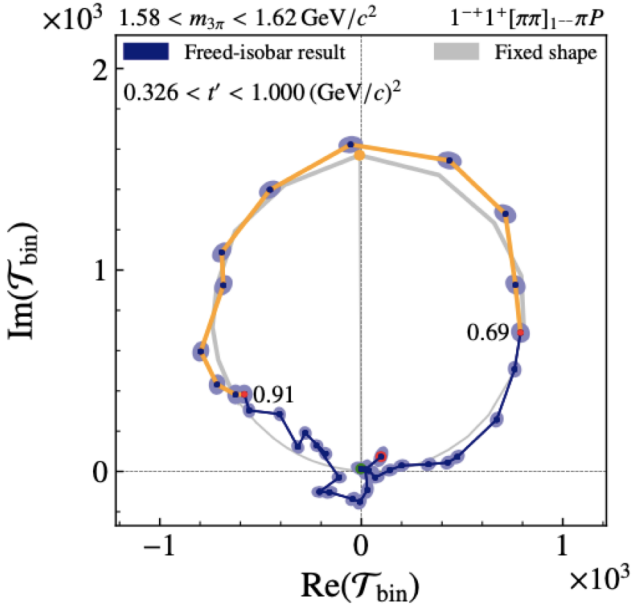
$$m^{\mathrm{PDG}}_{\pi(1800)} = 1812 \pm 12\,\mathrm{MeV}/c^2;\ \Gamma^{\mathrm{PDG}}_{\pi(1800)} = 208 \pm 12\,\mathrm{MeV}/c^2$$

- $\pi(1800)$ previously observed to decay in $f_0(980)\pi$ and $f_0(1500)\pi$ → "fixed f_0 isobars" assumed in the fit
- new analysis method: *this assumption can be tested!* → freed-isobar analysis

Isobar analysis in the spin-exotic $\pi_1(1600)$



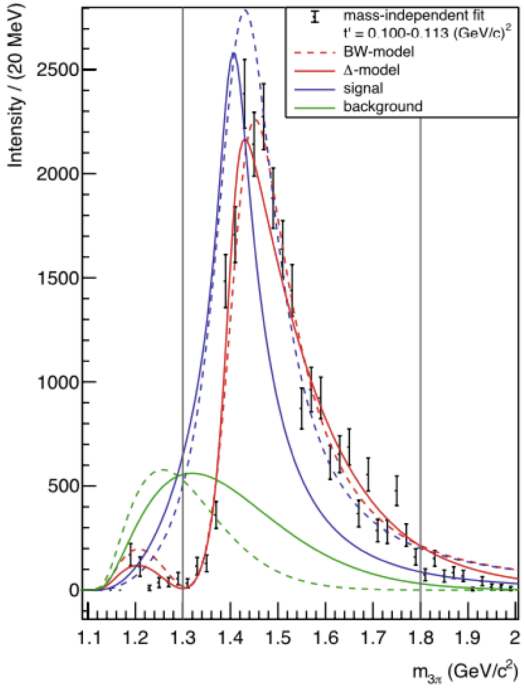


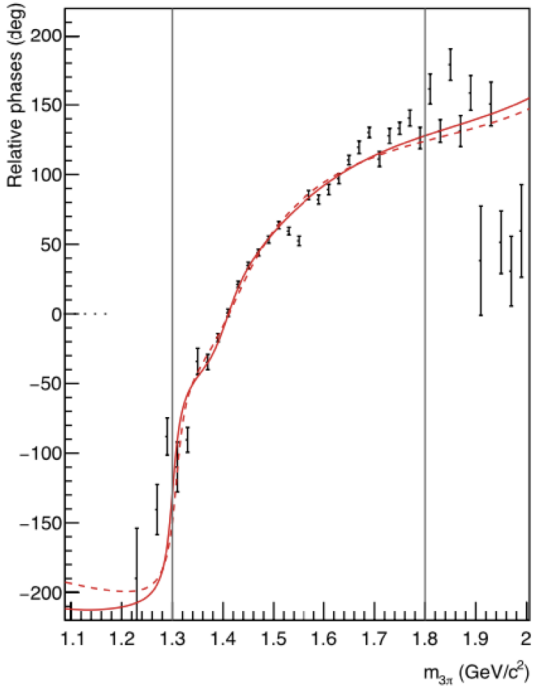


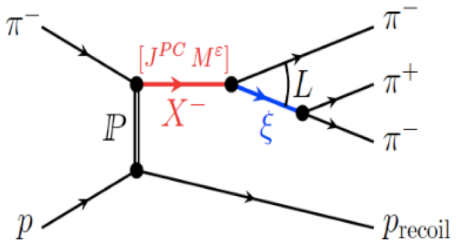
- detailed study of the much disputed $\pi_1(1600)$
- clean contribution of $\rho(770)$ can be constructed from the data
- some hint for higher-mass 1^{--} contributions

publication in preparation

Nature of the $a_1(1420)$

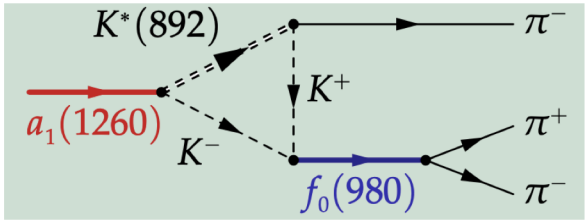






Natural explanation of the $a_1(1420)$ properties by triangle diagram:

manuscript under review



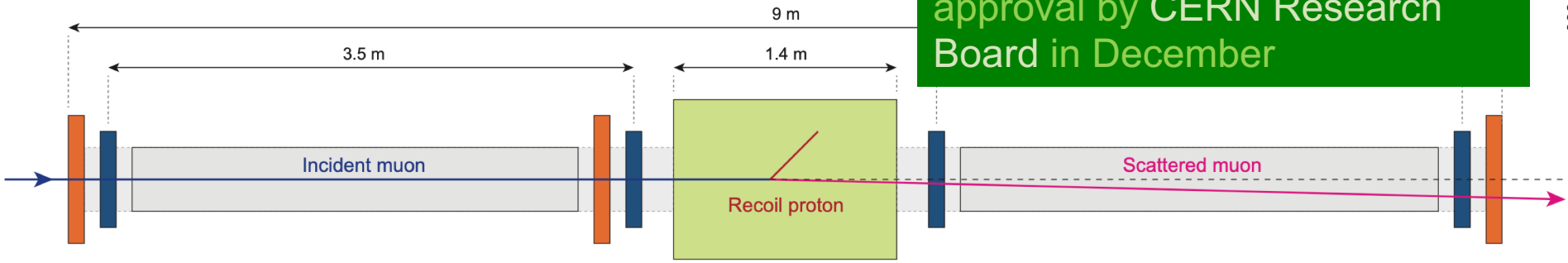
CERN-SPSC-2019-022; SPSC-P-360

Proposal for Measurements at the M2 beam line of the CERN SPS

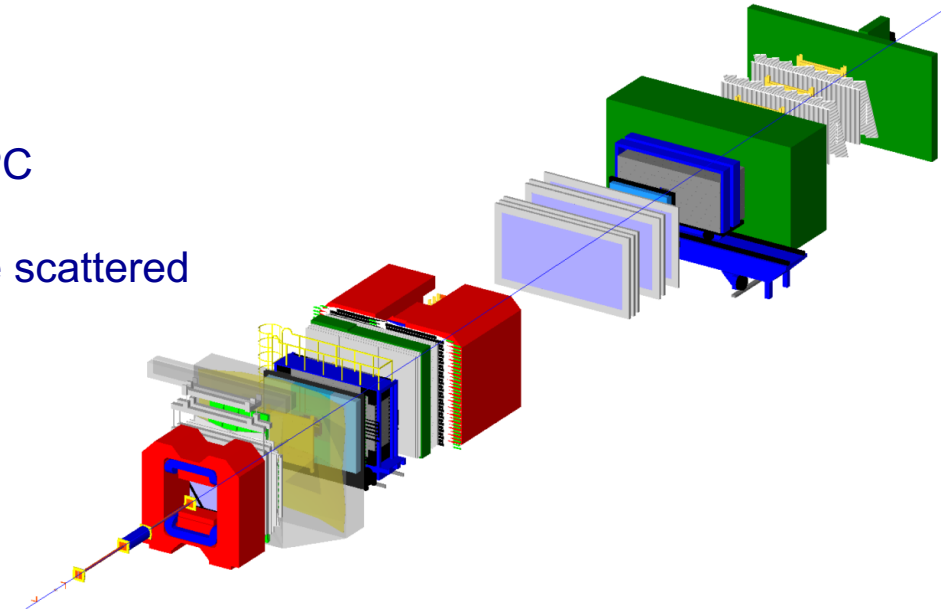
– Phase-1 –

COMPASS++*/AMBER†

Physics program recommended by SPSC in Oct 2020, approval by CERN Research Board in December



- 100 GeV muons of the CERN M2 beamline
- Protons in an active-target high-pressure TPC
- Silicon detectors for precision tracking
- 500µm SciFi stations for trigger/timing of the scattered muons
- inner tracking and ECAL of the COMPASS spectrometer

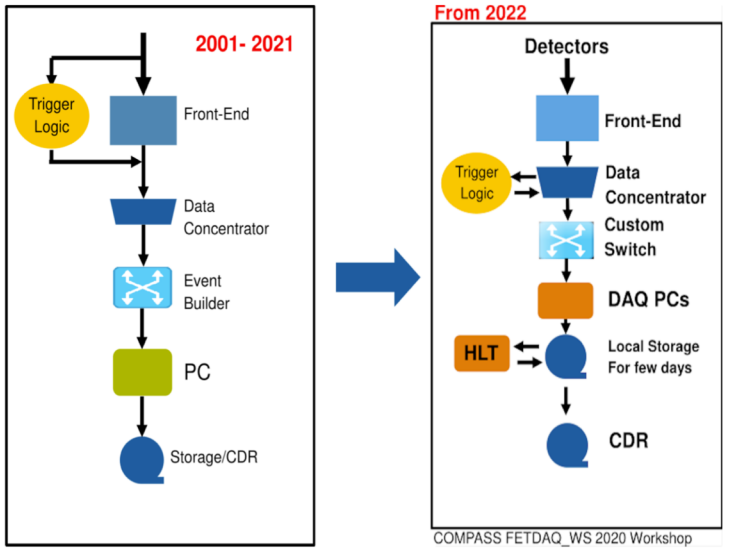


New Technology, one aspect: Trigger-less DAQ System

New DAQ development

A concept applying continuous DAQ based on the following principals:

- Continuously delivering front-end electronics
- Front-end data can be forwarded to trigger processors
- Hardware event builder stores data until trigger decision
- Status and Plans:
  → Adaption of DAQ firmware and software (within 2020)
  → Increase of data rate capability (2/10 GB/s 2022/2023)
  → Development of digital trigger (iFTDC card since 2019)

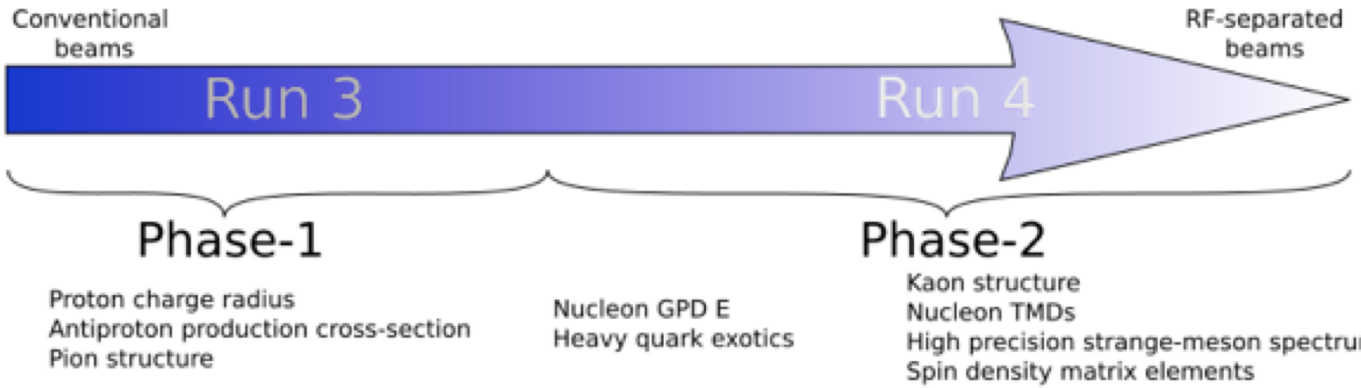


CERN-SPSC-2019-022; SPSC-P-360

COMPASS turns AMBER

Apparatus for Meson and Baryon Experimental Research

The long-range physics program



Physics goals						
Nucleon structure	Indirect DM search	Pion structure	Kaon structure	Strange-meson spectrum	Heavy quark exotics	Spin density matrix elements
			K-induced DY			
μ-p elastic scattering						
		π-induced DY	K-induced J/ψ production			
DVCS/DVMP on polarised target	$\bar{p}$ production cross section on H and He			K-induced spectroscopy	$\bar{p}$-induced spectroscopy	meson-induced vector-meson production
			Prompt photon production			
		π-induced J/ψ production				
$\bar{p}$-induced DY on polarised target			K-induced Primakoff			

Conclusions

- Data from 16 years of beam time under intense analysis
- Spectrometer is continuously upgraded and kept on state-of-the-art technology
- Final COMPASS beam time scheduled for 2021/22

- Future AMBER Collaboration in foundation, recently approved by the CERN Research Board
- MoU expected in first half of 2021
- Pilot run for the proton radius measurement in 2021
- Diverse future physics program for coming 10-15 years on hadron structure and spectroscopy