COMPASS++
AMBER

COMPASS++/AMBER
A New QCD Facility at CERN SPS

CFMS, tele-conference, Workshop on Pion and Kaon Structure Functions at the EIC, 2020/06/02

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Outline

1. Intro/LoI COMPASS++/AMBER
2. COMPASS++/AMBER Physics case:
    - Emergence of the hadronic mass (meson structure)
    - Proton spin structure
3. Emergence of the Hadronic Mass and not only:
    - Drell-Yan ➔ *Vincent Andrieux*
    - Charmonia production ➔ *Charles-Joseph Naim*
    - Prompt photons ➔ *Charles-Joseph Naim*
    - Primakoff and Spectroscopy ➔ ***Andrei Maltsev***
    - Search for dark matter
    - Proton radius
4. Proton spin structure
    - DVCS
    - Drell-Yan
5. Upgrades
6. COMPASS++/AMBER Phase-1/2 project status
7. Summary

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approximately 10 years-long effort, LoI is submitted in Jan. 2019

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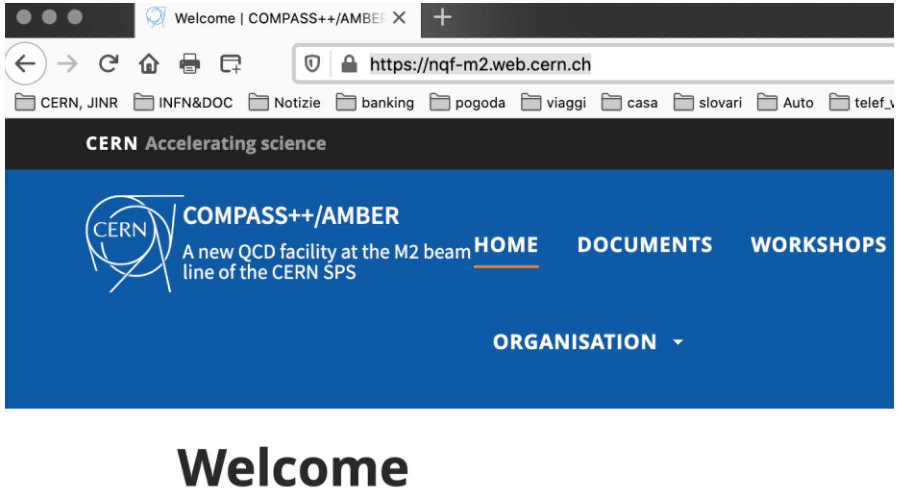
We have started to work on physics program of possible COMPASS successor ~ 10 years ago,

A Number of Workshops has been organized, for detail see COMPASS++/AMBER web page:

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



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-SPSC-2019-003
SPSC-I-250
January 25, 2019

http://arxiv.org/abs/1808.00848

Apparatus for Meson and Baryon Experimental Research

> 270 authors

[hep-ex] 25 Jan 2019

Letter of Intent:

A New QCD facility at the M2 beam line of the CERN SPS*

COMPASS++†/AMBER‡

B. Adams[13,12], C.A. Aidala[1], R. Akhunzyanov[14], G.D. Alexeev[14], M.G. Alexeev[41], A. Amoroso[41,42],

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A New QCD Facility at CERN SPS M2 beam line

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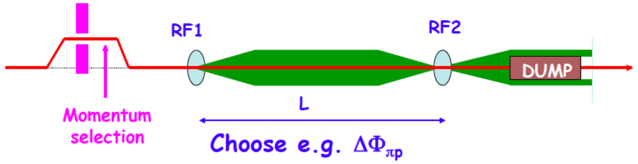
Program	Physics Goals	Beam Energy [GeV]	Beam Intensity [s^{-1}]	Trigger Rate [kHz]	Beam Type	Target	Earliest start time, duration	Hardware additions
muon-proton elastic scattering	Precision proton-radius measurement	100	$4 \cdot 10^6$	100	$\mu^\pm$	high-pressure H2	2022 1 year	active TPC, SciFi trigger, silicon veto,
Hard exclusive reactions	GPD E	160	$2 \cdot 10^7$	10	$\mu^\pm$	$NH_3^{\uparrow}$	2022 2 years	recoil silicon, modified polarised target magnet
Input for Dark Matter Search	$\overline{p}$ production cross section	20-280	$5 \cdot 10^5$	25	p	LH2, LHe	2022 1 month	liquid helium target
$\overline{p}$-induced spectroscopy	Heavy quark exotics	12, 20	$5 \cdot 10^7$	25	$\overline{p}$	LH2	2022 2 years	target spectrometer: tracking, calorimetry
Drell-Yan	Pion PDFs	190	$7 \cdot 10^7$	25	$\pi^\pm$	C/W	2022 1-2 years	
Drell-Yan (RF)	Kaon PDFs & Nucleon TMDs	~100	10^8	25-50	$K^\pm$, $\overline{p}$	$NH_3^{\uparrow}$, C/W	2026 2-3 years	"active absorber", vertex detector
Primakoff (RF)	Kaon polarisa-bility & pion life time	~100	$5 \cdot 10^6$	> 10	K^-	Ni	non-exclusive 2026 1 year	
Prompt Photons (RF)	Meson gluon PDFs	≥ 100	$5 \cdot 10^6$	10-100	$K^\pm$ $\pi^\pm$	LH2, Ni	non-exclusive 2026 1-2 years	hodoscope
K-induced Spectroscopy (RF)	High-precision strange-meson spectrum	50-100	$5 \cdot 10^6$	25	K^-	LH2	2026 1 year	recoil TOF, forward PID
Vector mesons (RF)	Spin Density Matrix Elements	50-100	$5 \cdot 10^6$	10-100	$K^\pm, \pi^\pm$	from H to Pb	2026 1 year	

Table 2: Requirements for future programmes at the M2 beam line after 2021. Muon beams are in blue, conventional hadron beams in green, and RF-separated hadron beams in red.

Conventional muon/hadron M2 beams



$\Delta\Phi = 2\pi\,(L\,f\,/\,c)\,(\beta_1^{-1} - \beta_2^{-1})$ with $\beta_1^{-1} - \beta_2^{-1} = (m_1^2 - m_2^2)/2p^2$

COMPASS++/AMBER PHASE-1

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PHASE-1

Conventional hadron and muon beams

2022 ➔ 2025 and beyond

PHASE-2

Conventional and RF-separated Hadron/Hadron and muon beam

2026 and beyond

Two bearing columns of the COMPASS++/AMBER

There are two bearing columns of the facility:

1. **The issue of the emergence of the hadron mass**
2. **Proton spin (largely addressed by COMPASS)**

FIRST, EHM:

How does the all visible matter in the universe come about and what defines its mass scale?

Unfortunately, the Higgs-boson discovery (even if extremely important) does NOT help to answer this question:

✓ The Higgs-boson mechanism produces only a small fraction of all visible mass

✓ The Higgs-generated mass scales explain neither the "huge" proton mass nor the 'nearly-masslessness' of the pion

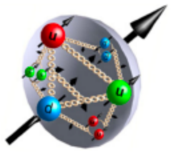
Pion

- $M_\pi \sim 140$MeV
- Spin 0
- 2 light valence quarks

Kaon

- $M_K \sim 490$MeV
- Spin 0
- 1 light and 1 "heavy" valence quarks

Proton



- $M_p \sim 940$MeV
- Spin 1/2
- 3 light valence quarks

Higgs generated masses of the valence quarks:

$M_{(u+d)}$ ~ 7 MeV $M_{(u+s)}$ ~ 100 MeV $M_{(u+u+d)}$ ~ 10 MeV

As Higgs mechanism produces a few percent of visible mass, thus the mass scale is defined by QCD mechanisms

EHM
(mass budget in proton, different QCD mechanism for Nambu-Goldstone bosons)

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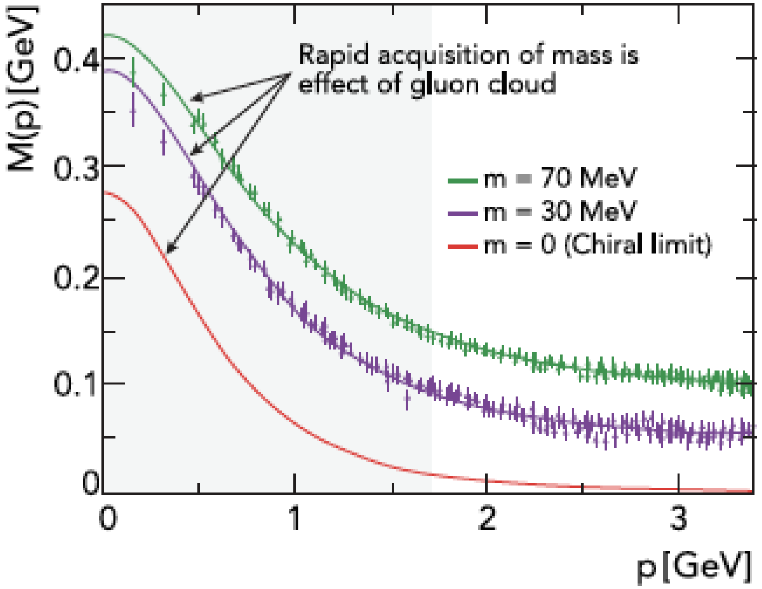
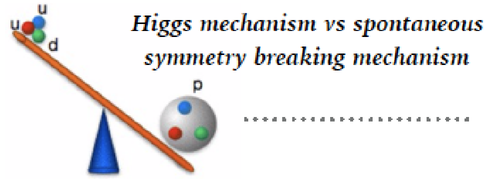
Dressed-quark mass function M(p)



The proton mass in the chiral limit is close to its nominal mass, as quark «gain» a mass evolving in to constituent one as its momentum became smaller.

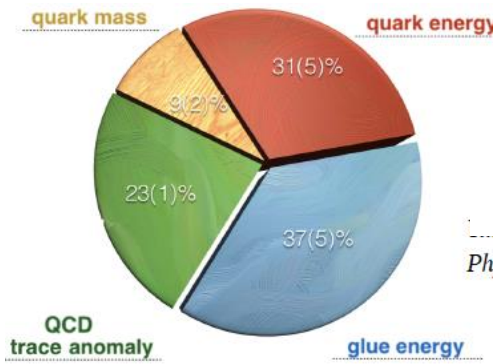
It is very different for pion and kaon (lightest Nambu-Goldstone modes) as they are massles in the chiral limit by definition.



Does this mean that their gluon content is equally small and different from the proton once? ➔ Must Study PDFs

One of the possible proton mass decomposition (calculation on lattice)

Yi-Bo Yong et al.,
Phys.Rev.Lett. 121 (2018) no.21, 212001



ss:

Relativistic motion | Quantum fluctuation

$$M = E_q + E_g + \chi_{m_q} + T_g$$

Quark Energy | Gluon Energy | Quark Mass | Trace Anomaly

COMPASS++/AMBER physics program
the issue of the emergence of the hadronic mass (EHM)

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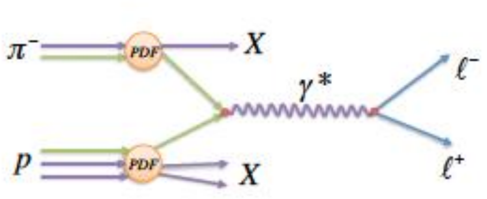
Questions to be answered:

- Mass difference pion/proton/kaon
- Mass generation mechanism (emergent mass .vs. Higgs)
- Gluon content, especially important pion/kaon striking difference

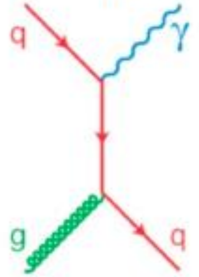
Methods:

Drell-Yan:



- 90's: NA3, NA10, E615
- 10's: COMPASS-II
- 20's: COMPASS++

Prompt photon production:



- 90's: NA24, W70
- 20's: COMPASS++

As well Charmonia production, pi/K diffractive scattering, pion/kaon polarizability

Drell-Yan: ***Vincent Andrieux (Tuesday)***
Charmonia&Prompt Photons: ***Charles-Joseph Naim (Thursday)***
Primakoff: ***Andrei Maltsev (Friday)***

EHM
COMPASS++/AMBER (pion induced DY) (Vincent)

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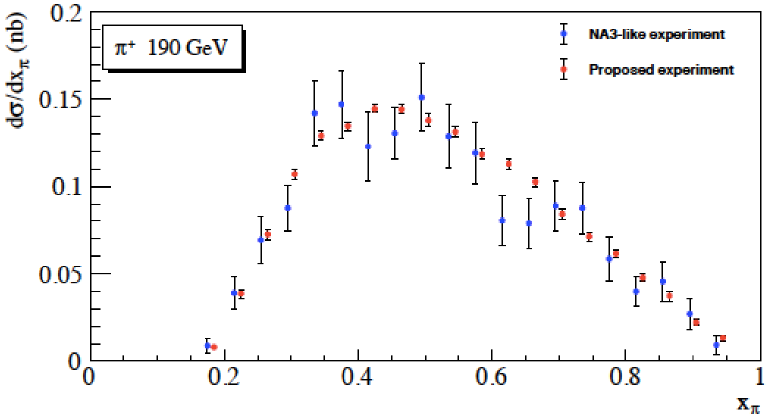
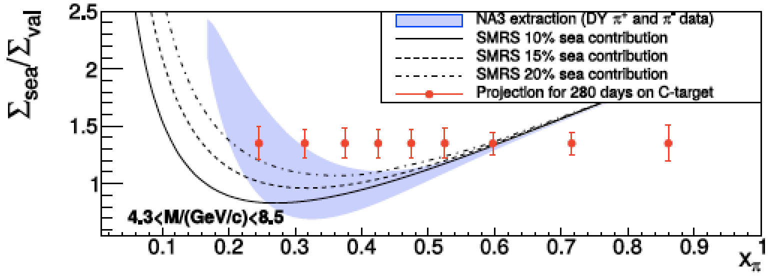
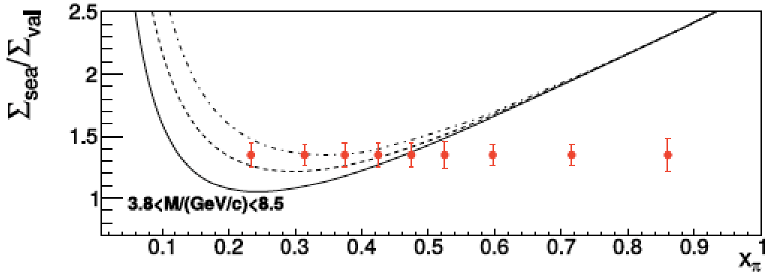






Pion structure in pion induce DY
Expected accuracy as compared to NA3

- $\Sigma_V = \sigma^{\pi^- C} - \sigma^{\pi^+ C}$: only valence-valence
- $\Sigma_S = 4\sigma^{\pi^+ C} - \sigma^{\pi^- C}$: no valence-valence
- Collect at least a **factor 10 more statistics** than presently available
- Minimize nuclear effects on target side
  - Projection for 2×140 days of Drell-Yan data taking
  - π^+ to π^- 10:1 time sharing
  - 190 GeV beams on Carbon target ($1.9\lambda^{\pi}_{int}$)
  - Improvement of shielding to double the intensity is under investigation

PHASE-1

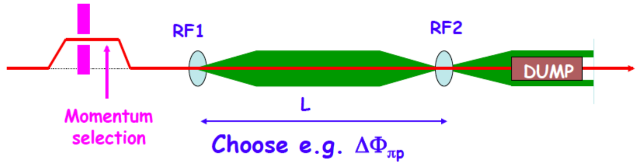
Experiment	Target type	Beam energy (GeV)	Beam type	Beam intensity (part/sec)	DY mass (GeV/c^2)	DY events
E615	20 cm W	252	π^+ π^-	17.6×10^7 18.6×10^7	4.05 – 8.55	5000 30000
NA3	30 cm H_2	200	π^+ π^-	2.0×10^7 3.0×10^7	4.1 – 8.5	40 121
	6 cm Pt	200	π^+ π^-	2.0×10^7 3.0×10^7	4.2 – 8.5	1767 4961
NA10	120 cm D_2	286 140	π^-	65×10^7	4.2 – 8.5 4.35 – 8.5	7800 3200
	12 cm W	286 194 140	π^-	65×10^7	4.2 – 8.5 4.07 – 8.5 4.35 – 8.5	49600 155000 29300
COMPASS 2015 COMPASS 2018	110 cm NH_3	190	π^-	7.0×10^7	4.3 – 8.5	35000 52000
This exp	75 cm C	190	π^+	1.7×10^7	4.3 – 8.5 4.0 – 8.5	21700 31000
		190	π^-	6.8×10^7	4.3 – 8.5 4.0 – 8.5	67000 91100
	12 cm W	190	π^+	0.4×10^7	4.3 – 8.5 4.0 – 8.5	8300 11700
		190	π^-	1.6×10^7	4.3 – 8.5 4.0 – 8.5	24100 32100

Isoscalar target + *Both positive and negative beams* + *High statistics*

COMPASS++/AMBER (kaon induced DY) (Vincent)

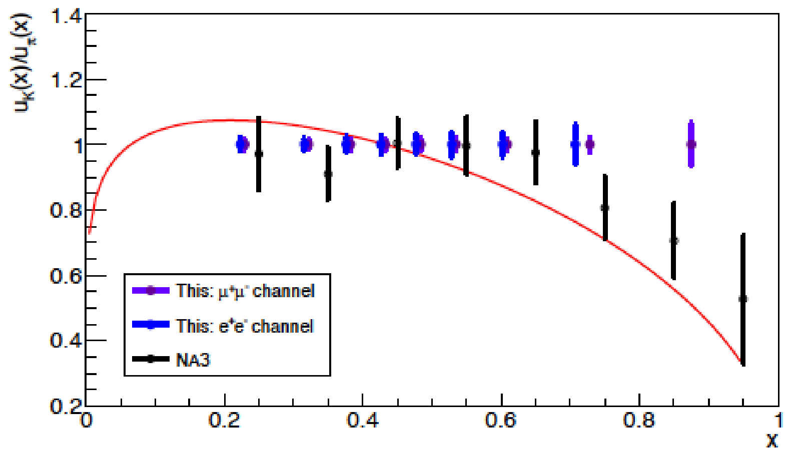
Extremely important to compare the gluon content of kaon and pion (emergent mass)

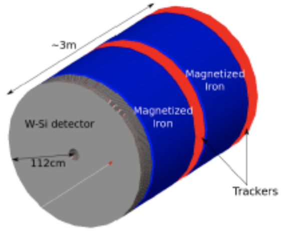
- **First ever DY measurements that could lead to kaon PDFs**
- Achievable statistics depends on beam energy and on kaon beam purity. Assuming $I = 7 \times 10^7\ s^{-1}$ with 30% kaons:
  - 40 kevents (K^-) and 5 kevents (K^+) @ 100 GeV
  - 25 kevents (K^-) and 3 kevents (K^+) @ 80 GeV



$\Delta\Phi = 2\pi\,(L\,f\,/\,c)\,(\beta_1^{-1} - \beta_2^{-1})$ with $\beta_1^{-1} - \beta_2^{-1} = (m_1^2 - m_2^2)/2p^2$

Projected statistical errors after 140 days of running, compared to NA3 stat. errors





Experiment	Target type	Beam type	Beam intensity (part/sec)	Beam energy (GeV)	DY mass (GeV/c^2)	DY events $\mu^+\mu^-$	e^+e^-
NA3	6 cm Pt	K^-		200	4.2 – 8.5	700	0
This exp.	100 cm C	K^-	2.1×10^7	60	4.0 – 8.5	12,000	8,000
				70	4.0 – 8.5	18,000	10,900
				80	4.0 – 8.5	25,000	13,700
				100	4.0 – 8.5	40,000	17,700
				120	4.0 – 8.5	54,000	20,700
		K^+	2.1×10^7	60	4.0 – 8.5	1,000	600
				70	4.0 – 8.5	1,800	900
				80	4.0 – 8.5	2,800	1,300
				100	4.0 – 8.5	5,200	2,000
				120	4.0 – 8.5	8,000	2,400
This exp.	100 cm C	π^-	4.8×10^7	60	4.0 – 8.5	31,000	20,500
				70	4.0 – 8.5	50,800	25,400
				80	4.0 – 8.5	65,500	29,700
				100	4.0 – 8.5	95,500	36,000
				120	4.0 – 8.5	123,600	39,800

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Charmonium (Charles)

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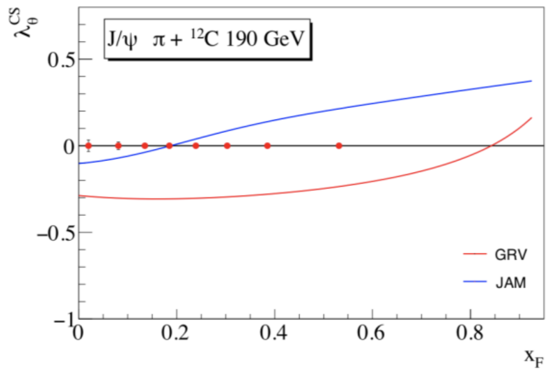
PHASE-1

Collected simultaneously with DY data, with large counting rates

Physics objectives:

- Study of the J/ψ (charmonia) production mechanisms (*gg–fusion vs $q\bar{q}$–annihilation*), comparison of **CEM** and **NRQCD**
- Probe gluon and quark PDFs of pion
- $\boldsymbol{\Psi}$(2S) signal study, free of feed-down effect from and χ_{c1} χ_{c2}

Method: Model depended separation of contributions from two competent processes using data collected with both positive and negative beams



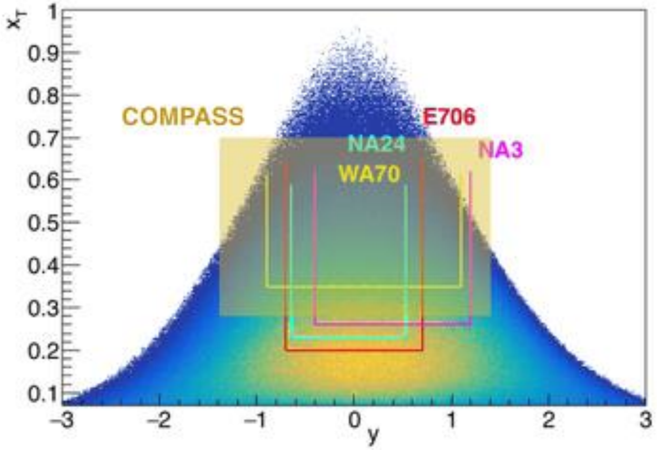
Experiment	Target type	Beam energy (GeV)	Beam type	J/ψ events
NA3 [76]	Pt	150	π^-	601000
		280	π^-	511000
		200	π^+	131000
			π^-	105000
E789 [129, 130]	Cu	800	p	200000
	Au			110000
	Be			45000
E866 [131]	Be Fe Cu	800	p	3000000
NA50 [132]	Be	450	p	124700
	Al			100700
	Cu			130600
	Ag			132100
	W			78100
NA51 [133]	p	450	p	301000
	d			312000
HERA-B [134]	C	920	p	152000
COMPASS 2015	110 cm NH_3	190	π^-	1000000
COMPASS 2018				1500000
This exp	75 cm C	190	π^+	1200000
			π^-	1800000
			p	1500000
	12 cm W	190	π^+	500000
			π^-	700000
			p	700000

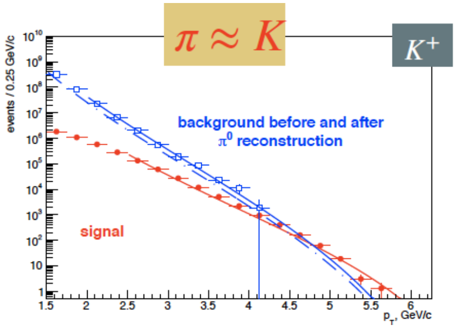
COMPASS++/AMBER (Prompt Photons) (Charles)

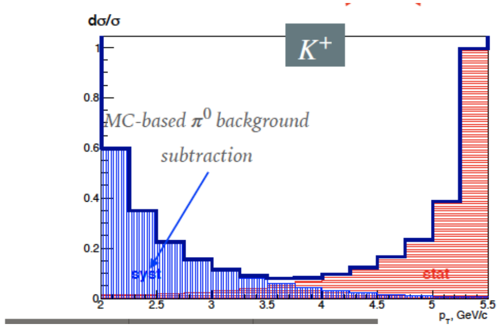
At the moment there is no experimental information about gluon contribution in kaon. Calculations based on Dyson-Schwinger equations predict 6 times smaller contribution at hadronic scale in respect to pion (Phys. Rev. D93 (7) (2016) 074021)

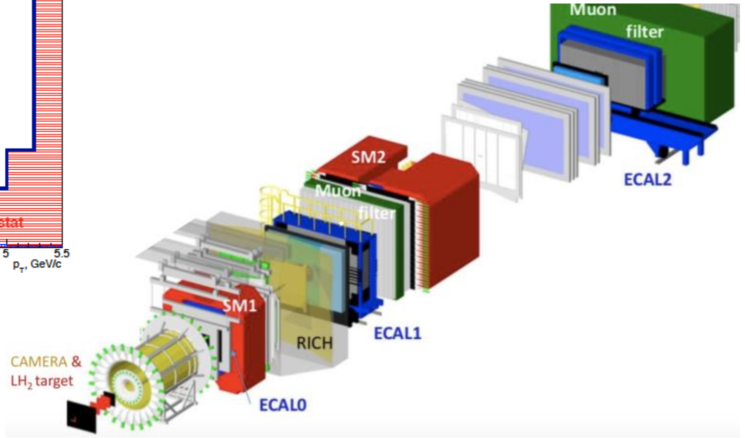
Pythia-based MC simulation for prompt photons production was used for preliminary estimation of kinematic range accessible at COMPASS. It was compared with corresponding ranges accessible by previous experiments with pion beams.

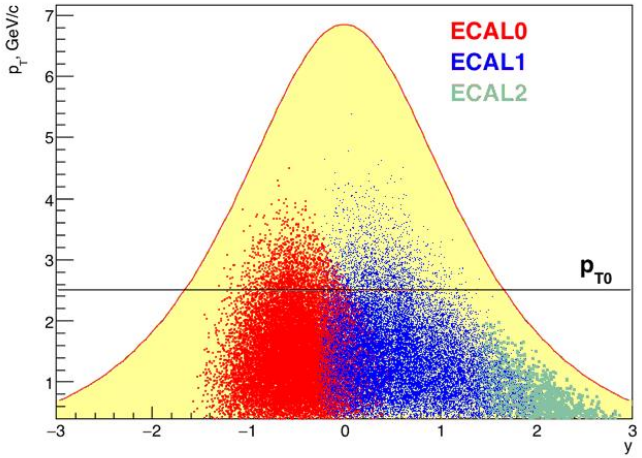
Possibilities to identify signal and reject background were tested. Some optimization of the setup from point of the material budget was tested.











CERN

Search for Dark Matter
Absolute cross section measurement p+He--> pbar+X

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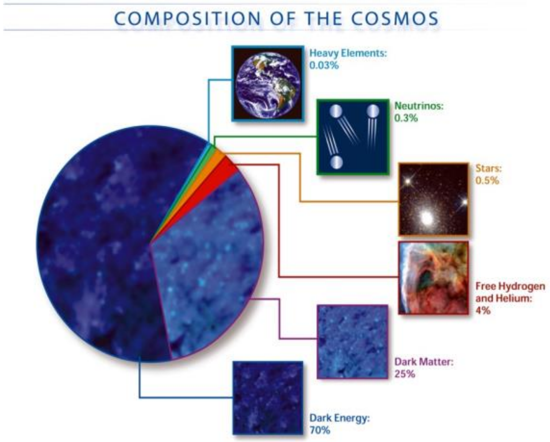
PHASE-1



-New AMS(2) data – the antiparticle flux is well known now (few % pres.) (http://dx.doi.org/10.1103/PhysRevLett.117.091103)

- Two type of processes contribute – SM interactions (proton on the ISM with the production for example antiprotons in the f.s.) and contribution from dark particle – antiparticle annihilation;

- In order to detect a possible excess in the antiparticles flux a good knowledge of inclusive cross sections of p-He interaction with antiparticles in the f.s. is a must, currently the typical precision is of 30-50%.

COMPASS++ from a few tens of GeV/c up to 250 GeV/c, in the pseudorapidity range 2.4 < h < 5.6.

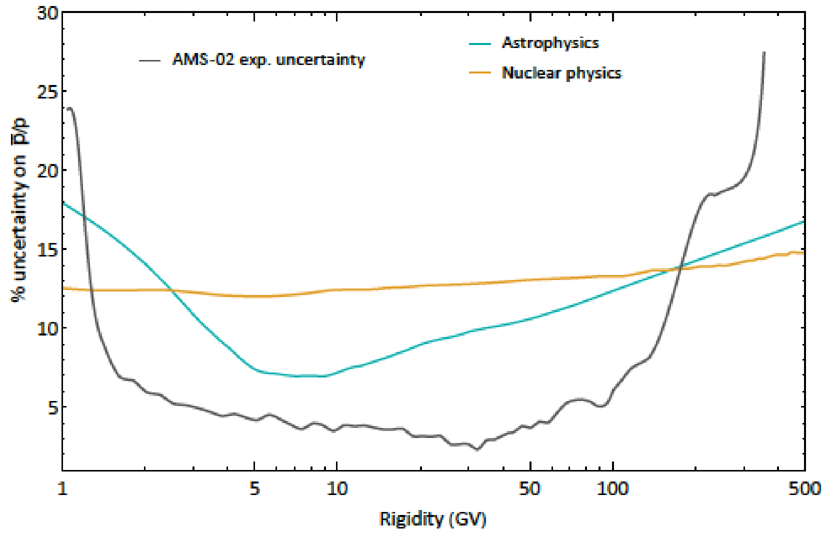
We performed simulation with TGEANT (GEANT4 based COMPASS MC), using FLUKA generator or the internal TGEANT generator:

2009 COMPASS hadron setup, 190 GeV beam.

Italian contributors (new to COMPASS):

AMS: P. Zuccon, F. Nozzoli (UniTN, TIFPA and INFN),
N. Masi, L. Quadrani, A. Contin (UniBO and INFN),
Theoretical Physicist: F. Donato, M. Kosmeier (UniTO e INFN)

Goal is to measure the double differential (momentum and pseudorapidity) anti-p cross production from p+p and p+He at different proton momenta (50, 100, 190, 250 GeV/c).



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antimatter production x-section

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PHASE-1

We show the impact of the proposed p + p measurements on constraining the production of cosmic anti-protons versus their kinetic energy. Each curve represents the fraction of anti-proton production as constrained by our cross-section measurements p-p, p-He and He-p channels, compared to NA61 (p-p) and LHCb (p-He) measurements

p-p channel, in three different energy ranges

100-190 GeV/c

50-190 GeV/c

50 - 250 GeV/c

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LHCb

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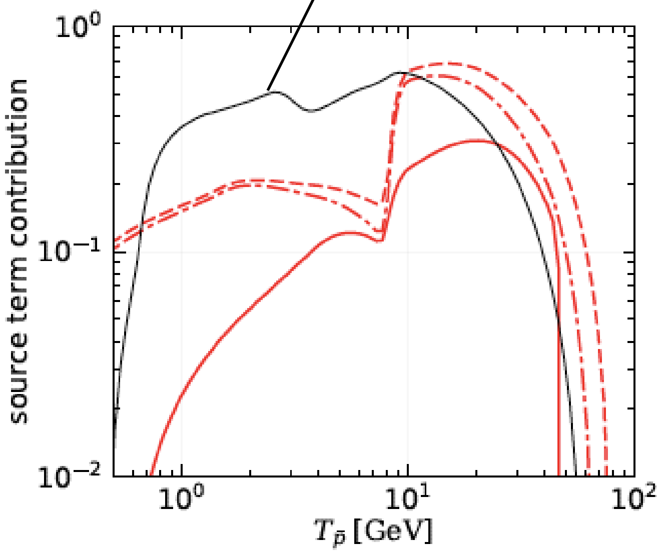
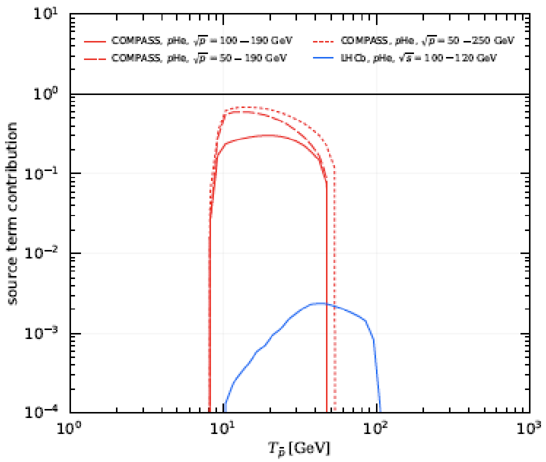
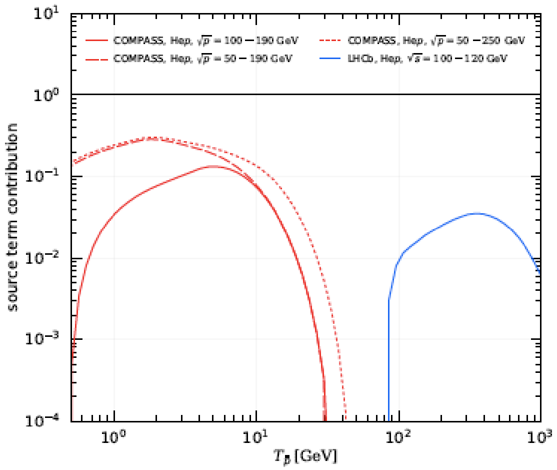
NA61 (20-158 GeV/c)



p-He and He-p channels





https://indico.cern.ch/event/820869/

CERN

Proton Radius Puzzle

PHASE-1

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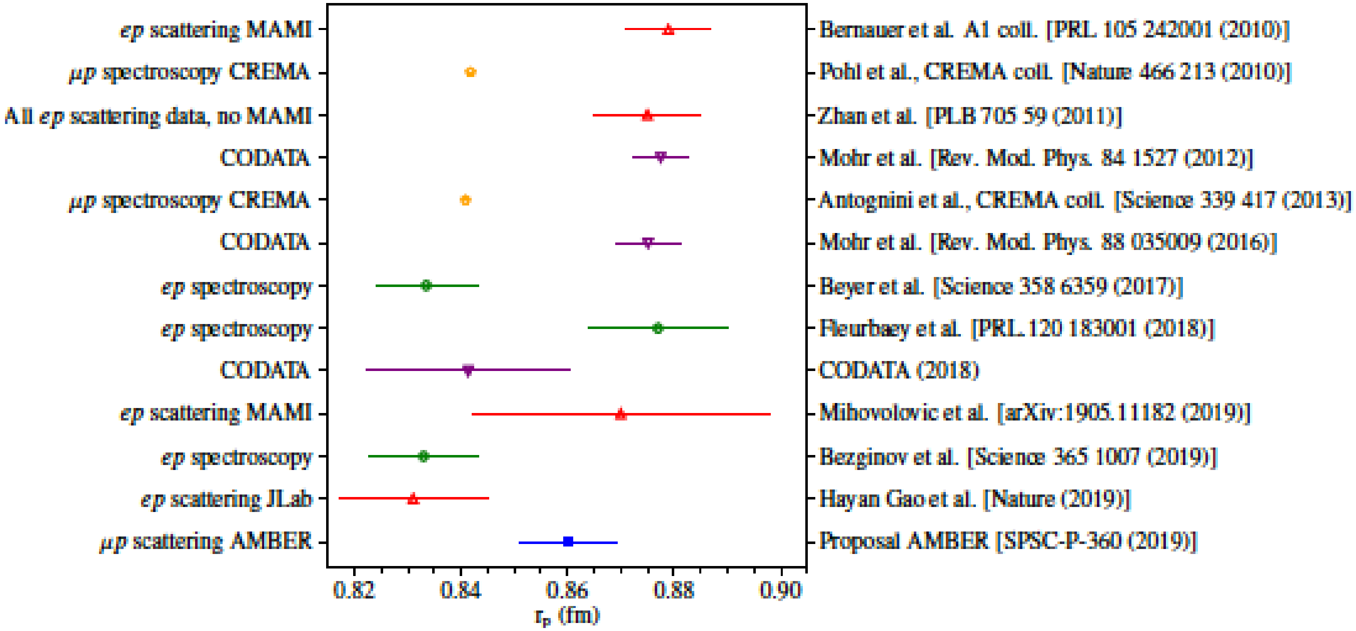
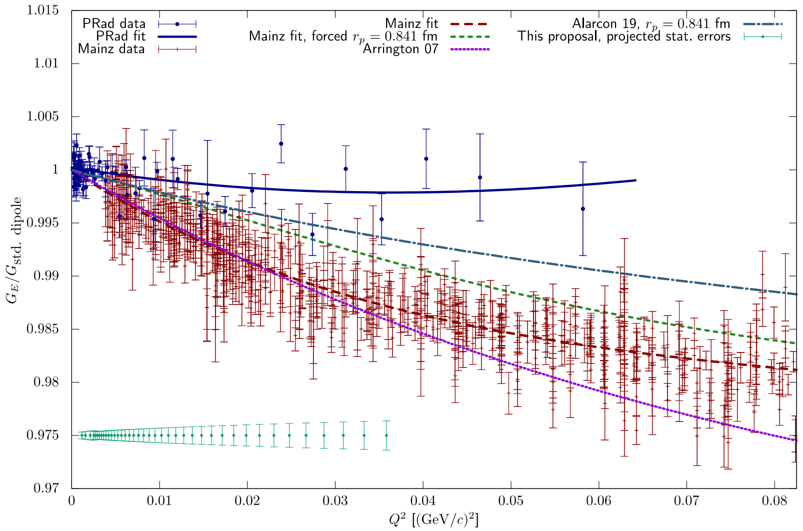


	ep	μp
Spectroscopy	New measurements with ▪ lower systematics ▪ new transitions	✔
Scattering	New measurements with ▪ lower systematics ▪ reaching lower Q^2 ProRAD, ULQ2, ISR @ MESA, PRad	No data yet. MUSE at PSI coming soon AMBER



- **Recent data points of spectroscopy and scattering experiments added**
- **Some trending towards the small-radius (0.84 fm) scenario**
- **Electron scattering analysis has determined a larger radius (0.88 fm), but newly published PRad data shows the smaller one – to be cross-checked by other experiments**
- **Precision measurement of the proton form factors, especially at lower Q^2 are urgently needed**

Proton Radius Puzzle
(Set-up and Simulations)

PHASE-1

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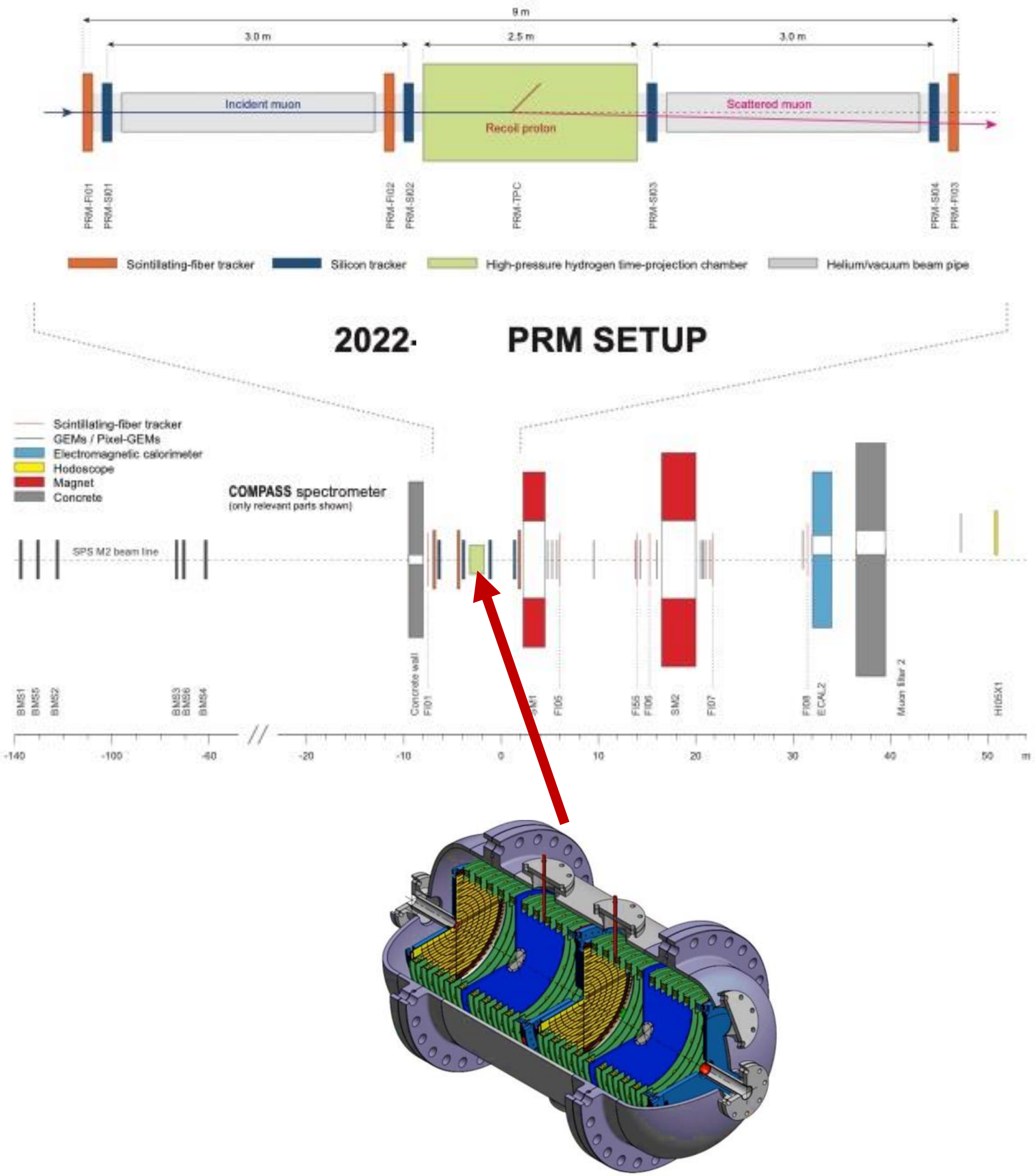
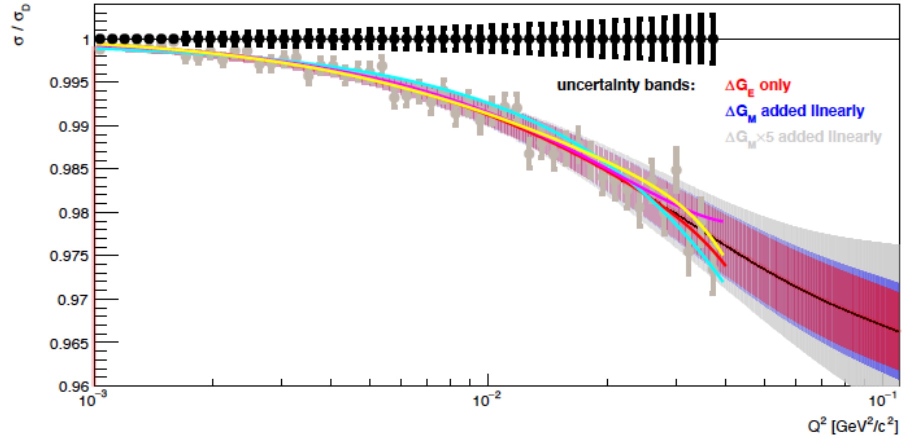




statistical precision of the proposed measurement, down to Q2 = 0,001 GeV^2/c^2, Cross section is normalised to the G_D - dipole form factor

Proton spin structure

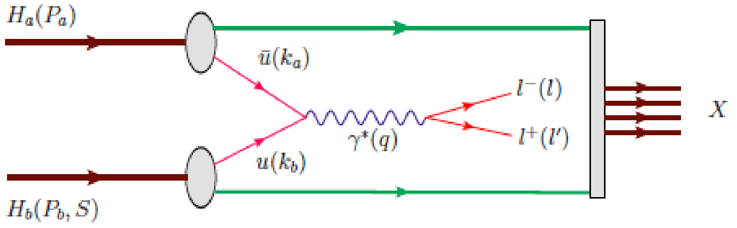
Huge progress has been done by COMPASS on resolving spin crisis and to study 3D structure of the nucleon in SIDIS, unpolarised DVCS and pion induced Polarised DY. The final year of the SIDIS running with transversely polarised deuteron target is approved BY SPSC and scheduled to 2021. This will finalise our data set to TMDs in SIDIS process.

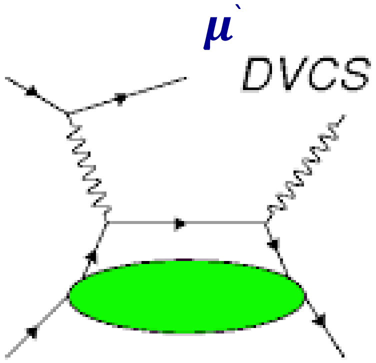
Still new, unique measurements can be done to access:

- Orbital momentum of quarks and gluons via polarised DVCS process
- TMDs, in particular Sivers and Boer-Mulders functions in a clean, nearly Model independent way via antiproton induced DY

Methods:

Drell-Yan





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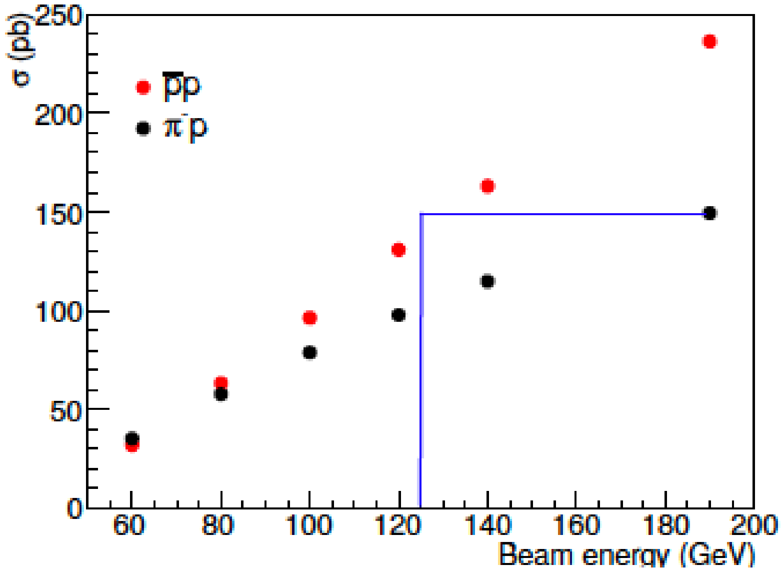
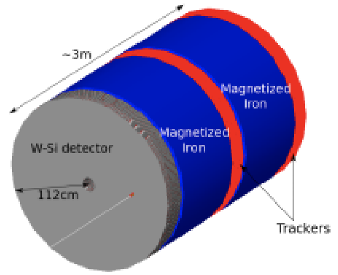
TMDs in antiproton induced DY



- cross-sections for $\bar{p}$ induced-DY at 120 GeV $\sim$ π^- induced-DY at 190 GeV
- Combined statistics from $\mu^+\mu^-$ and e^+e^- channels $\sim$ 2 years of COMPASS-II data taking

- Antiproton-induced polarised DY makes **TMD's extraction model independent**
- Allows to profit from good knowledge of proton PDFs (from SIDIS) and as alternative probe
  permits to test TMDs universality
- New data on all TMDs induced asymmetries in both High Mass and J/Ψ regions:
  1. Model independent Boer-Mulders (quark-spin – quark-k_T correl.) extraction (CPT equiv.)
  2. Model independent Transversity extraction
  3. Lam-Tung relation for antiprotons (QCD effects)
  4. Sivers asymmetry (nucleon-spin – quark-k_T correlations) with no uncertainty from pion PDFs
  5. Sivers function for gluons (J/Ψ regions)
  6. Flavour separated TMDs extraction
  7. EMC effects & flavour dependent EMC effects

Experiment	Target type	Beam type	Beam intensity (part/sec)	Beam energy (GeV)	DY mass (GeV/c^2)	DY events $\mu^+\mu^-$	DY events e^+e^-
This exp.	110cm NH_3	$\bar{p}$	3.5×10^7	100	4.0 – 8.5	28,000	21,000
				120	4.0 – 8.5	40,000	27,300
				140	4.0 – 8.5	52,000	32,500



COMPASS++/AMBER General Upgrades

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Major part of the spectrometer on floor since 2001,
substantial upgrade is required

- New front-end electronics (FEE) and trigger logics that are compatible with triggerless readout, which include an FPGA-based TDC with time resolution down to 100 ps and a digital trigger that is capable of rates up to 100-200 kHz (Sec. 5.2.1).
- New large-size PixelGEMs as replacement and spares for existing large-area GEMs (Sec. 5.2.2).
- New large-area micro-pattern gaseous detectors (MPGD) based on GEMs or Micromegas technology to replace existing MWPCs (Sec. 5.2.3).
- High-rate-capable CEDARs (Sec. 5.2.4) for all hadron-beam programmes to identify the desired beam particle.
- The existing RICH-1 will be required by the spectroscopy programmes (Secs. 3.2 and 4.2), the anti-matter cross section measurement (Sec 3.3), and the Primakoff programme (Sec. 4.5). A new, high-aperture RICH-0 would be desirable for these programmes in order to identify hadrons at lower momenta (Sec. 5.2.5).

COMPASS++/AMBER Specific Upgrades

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- muon-proton elastic scattering (more in Sec. 5.3.2): high-pressure active TPC target (similar to A2 at MAMI) or hydrogen tube surrounded by SciFis; SciFi trigger system on scattered muon; silicon trackers to veto on straight tracks (kink trigger).
- Hard exclusive reactions (more in Sec. 5.3.3): 3-layer silicon detector inside the existing but modified transversely polarised NH_3 target, which operates at very low temperature, for tracking of the recoil proton produced in DVCS, as well as for PID via dE/dx. Alternatively: SciFis.
- Input for DMS: liquid helium target.
- $\overline{p}$-induced spectroscopy (more in Sec. 5.3.4): target spectrometer (tracking, barrel calorimeter) similar to WASA at COSY [199]; target: LH2, foil, wire.
- Drell Yan: high-purity and high-efficiency dimuon trigger; dedicated precise luminosity measurement; dedicated vertex-detection system; beam trackers; targets: ^{6}LiD $\uparrow$, and C/W.
- Drell-Yan (RF) (see also Sec. 5.3.5): due to the lower beam energy, a wide aperture will be needed (up to $\pm$300 mrad): a "magnetised spectrometer" (active absorber) is under consideration. It could possibly be similar to Baby MIND at JParc [200] ("3-in-1" detector, spectrometer magnet, absorber).
- Prompt Photons (RF): 20-30 cm steel absorber upstream of the target; new hodoscope upstream of the existing electromagnetic calorimeter ECAL0; transparent setup with as little material as necessary.
- K-induced spectroscopy (RF): uniform acceptance; existing electromagnetic calorimeters; recoil TOF detector (see Fig. 21, called "RPD" there).

COMPASS++/AMBER – Proposal Phase-1

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EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-SPSC-2019–022
SPSC-P-360
September 30, 2019

51 institutions, ~260 authors,
19 new institutions with respect to COMPASS
(USA, Germany, Italy, Russia etc.)

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

– Phase-1 –

COMPASS++[*]/AMBER[†]

B. Adams[14,13], C.A. Aidala[1], G.D. Alexeev[15], M.G. Alexeev[42,43], A. Amoroso[42,43], V. Andrieux[45,20],

COMPASS++/AMBER – Phase - 1
Interactions with SPSC I

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SPSC stays for "SPS and PS Experiments Committee"
The committee was created at the end of 1989 to replace the SPSC and PSCC Committees. The mandate of the committee is to referee the requests from the experimental teams on the basis of their physics interest and of the availability of the accelerators. It meets 4 times a year. The SPSC recommendations are sent to the Research Board, which takes the decisions.

The Phase-1 Proposal was submitted to the SPSC in the end of September 2019, it was discussed at the SPSC meetings in October 2019, January and April 2020.

We had two session of questions-answers with our SPSC referees, which results in ~100 page long document. The review process is till ongoing, we still have to address few question circulated to us after April 2020 meeting of SPSC.

VERY IMPORTANT: we receive for the first time very positive statement from the April SPSC meeting:
The physics potential of 150d mu-p elastic scattering and of a hadron-beam program for measuring the anti-p production cross-section in p-He collision as well as for pion-induced Drell-Yan and charmonium production have been recognized.

COMPASS++/AMBER – Phase - 1
Interactions with SPSC II

The Committee is presently not in a position of giving a recommendation for 2022 and in particular 2023++, also in view of the impact the ESPP update and COVID-19 will have on the NA programs (more specifically in this respect the M2 beam line programs). (ESPP – European Strategy in Particle Physics update initiative, All new proposal have to wait till this document will became public, now classified for CERN RB internal use only).

Our expectations after several interactions with SPSC members and CERN Research Director Eckhard Elsen:

- ESPP recommendations will became public at the June 2020 Meeting of the CERN RB

- We expect COMPASS++/AMBER Phase-1 Proposal to be recommended by SPSC in Sep. 2020

- In case of SPSC recommendation COMPASS++/AMBER Phase-1 Proposal will be approved by Research Board in December 2020

COMPASS++/AMBER – Phase - 2
input from the CERN authorities (RD E.Elsen)

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In May we had a first very positive input on COMPASS++/AMBER Phase-2 (physics with RF separated kaon/antiproton beams mostly) from CERN Authorities (RD E.Elsen)

- The idea of new (i.e. RF separated) hadron beams found a support and interest in the SPSC
- The proposal is not competing or in any case might not be conditioned by the decision on new BeamDump facility construction in the North Area (SHIP experiment etc.)
- We were encouraged to go ahead with our plans and submit Phase-2 Proposal in a shortest possible time (according to our plans we will submit is in the end of 2020, beginning of 2021)

Thus we will proceed in full swing with a preparation of the AMBER Phase-2 Proposal, major part of it dedicated to the pion/kaon structure study

Summary

- Pion and Kaon structure and Emergence of Hadron Mass study is a major goal of the whole COMPASS++/AMBER enterprise

- We expect Phase-1 Proposal (conventional hadron/muon beams) to be approved by the end of 2020

- We are going in full swing with preparation of the Phase-2 proposal to be submitted at the end of 2020/beginning of 2021.

BACK UP

RF separated antiproton/kaon beam – a missing ingredient in the spin/mass crises resolving

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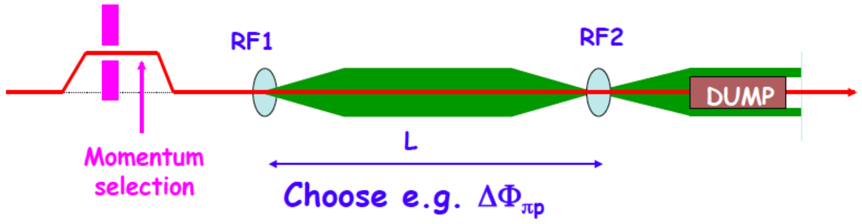

$\Delta\Phi = 2\pi\,(L\,f\,/\,c)\,(\beta_1^{-1} - \beta_2^{-1})$ with $\beta_1^{-1} - \beta_2^{-1} = (m_1^2 - m_2^2)/2p^2$

"Normal" h^- beam composition:
~97% (π) ~2.5%(K) ~0.5% (pbar)

Assumptions:

– 8 x 10^7 antiprotons for 10^{13} ppp (10 seconds) (optimistic estimate by Lau Gatignon);
– we assume here 4 x 10^{13} protons.

Antiprotons RF separated beam: 3.2 x 10^7 /s - Gain is a factor of 50 compared to the standard h^- beam for Drell-Yan experiment (~1% of h^- beam 6x10^7 /s dominated by π^-)

Using the same assumption for RF separated kaon beam, possible kaon beam intensity is 8 x 10^6 /s - Gain is a factor of 80 compared to to the standard "spectroscopy" h^- beam

High intensity RF separated beam will provide unique opportunities for Hadron Spectroscopy, Drell-Yan physics, Prompt Photon production etc.