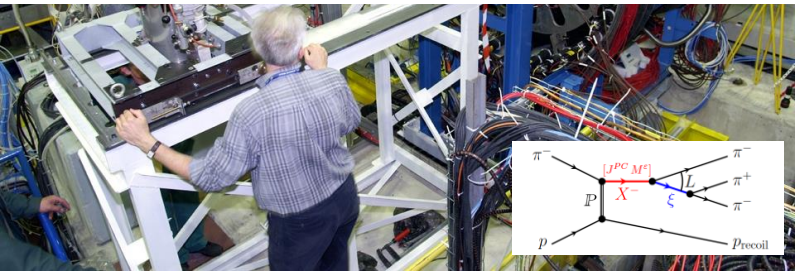
Outline

1. New QCD Facility at CERN SPS (COMPASS++/AMBER)
   - Web page
   - Summary for ESPP
   - LoI submitted
   - Physics
   - Community
2. PBC QCD summary
3. Proton radius – first results of 2018 beam test
4. Next steps
5. Summary

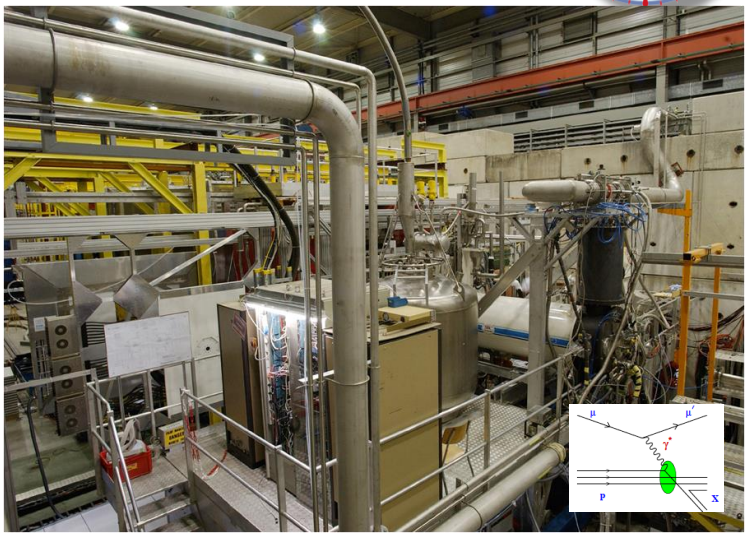
COMPASS QCD facility at SPS M2 beam line (CERN)
(secondary hadron and lepton beams)

Exotic states, chiral dynamics



Hadron Spectroscopy & Polarisability

COMPASS-I
1997-2011

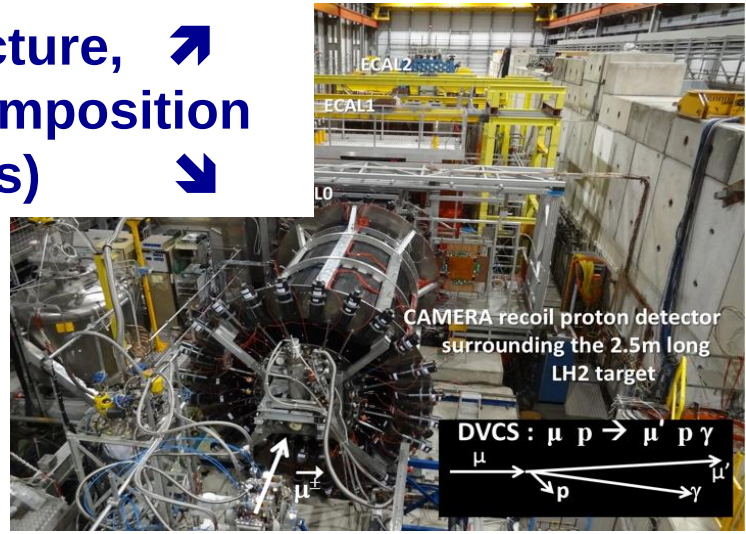


Polarised SIDIS

Polarised Drell-Yan

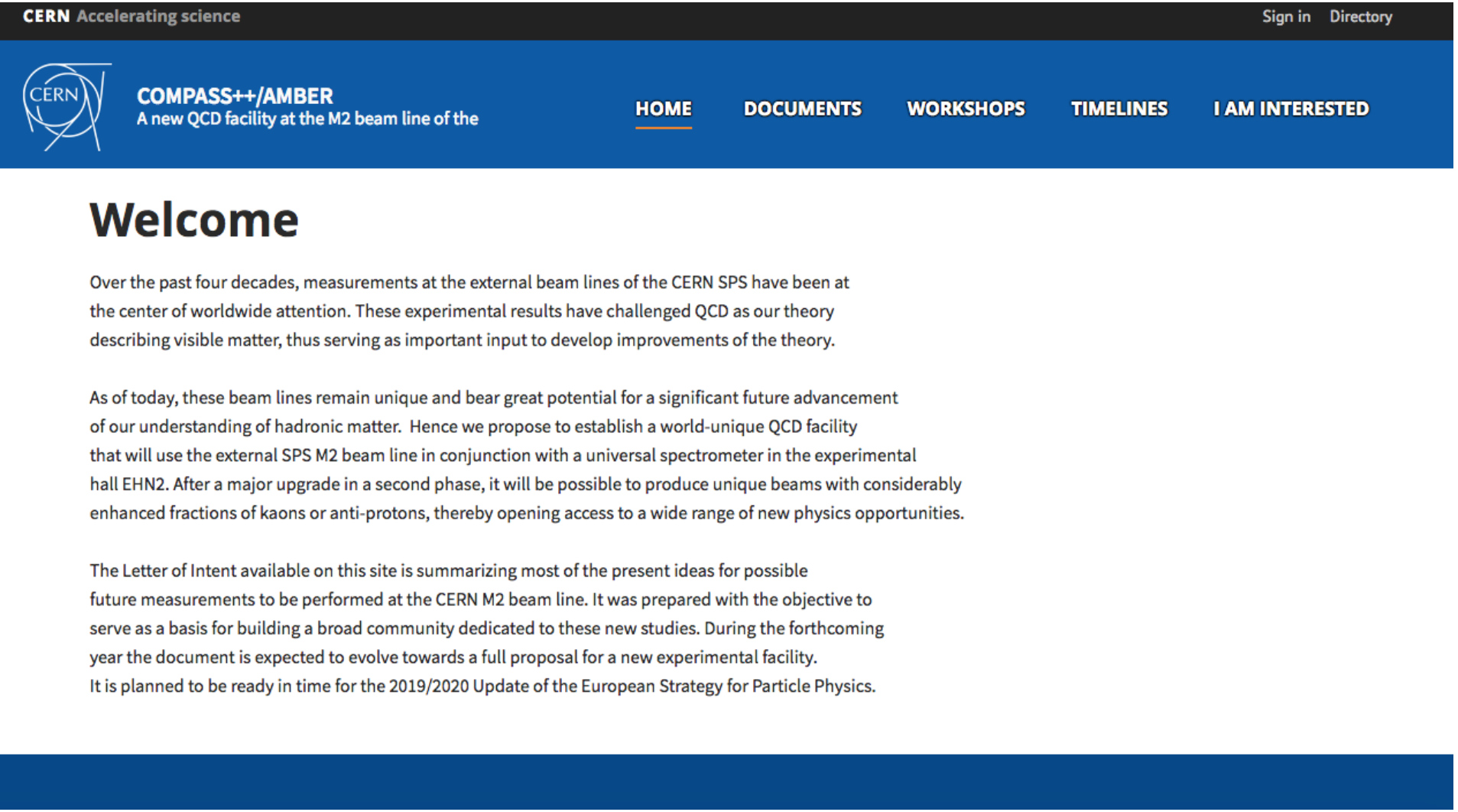
3D hadron structure,
Proton spin decomposition
(spin crisis)

COMPASS-II
2012-2020



DVCS (GPDs) + unp. SIDIS

New CERN SPS based QCD facility
COMPASS++/AMBER
Web page I: https://nqf-m2.web.cern.ch/



New CERN SPS based QCD facility
COMPASS++/AMBER
Web page II: https://nqf-m2.web.cern.ch/

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COMPASS++/AMBER
A new QCD facility at the M2 beam line of the

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Workshops

List of workshops where a New QCD facility at the M2 beam line of the CERN SPS was discussed.

10. **Mapping Parton Distribution Amplitudes and Functions", ECT***

    10. 9. 2018 - 14. 9. 2018, https://indico.ectstar.eu/event/22/overview

    - Studying meson and proton structure at the CERN M2 beam line, V. Andrieux https://indico.ectstar.eu/event/22/contributions/502/attachments/390/535/Andrieux_Trento10092018.pdf

9. **MiniWorkshop on A New QCD Facility at the SPS (CERN) after 2021**

    20. 6. 2018, CERN, https://indico.cern.ch/event/737176/

8. **PBC Working Group Meeting**

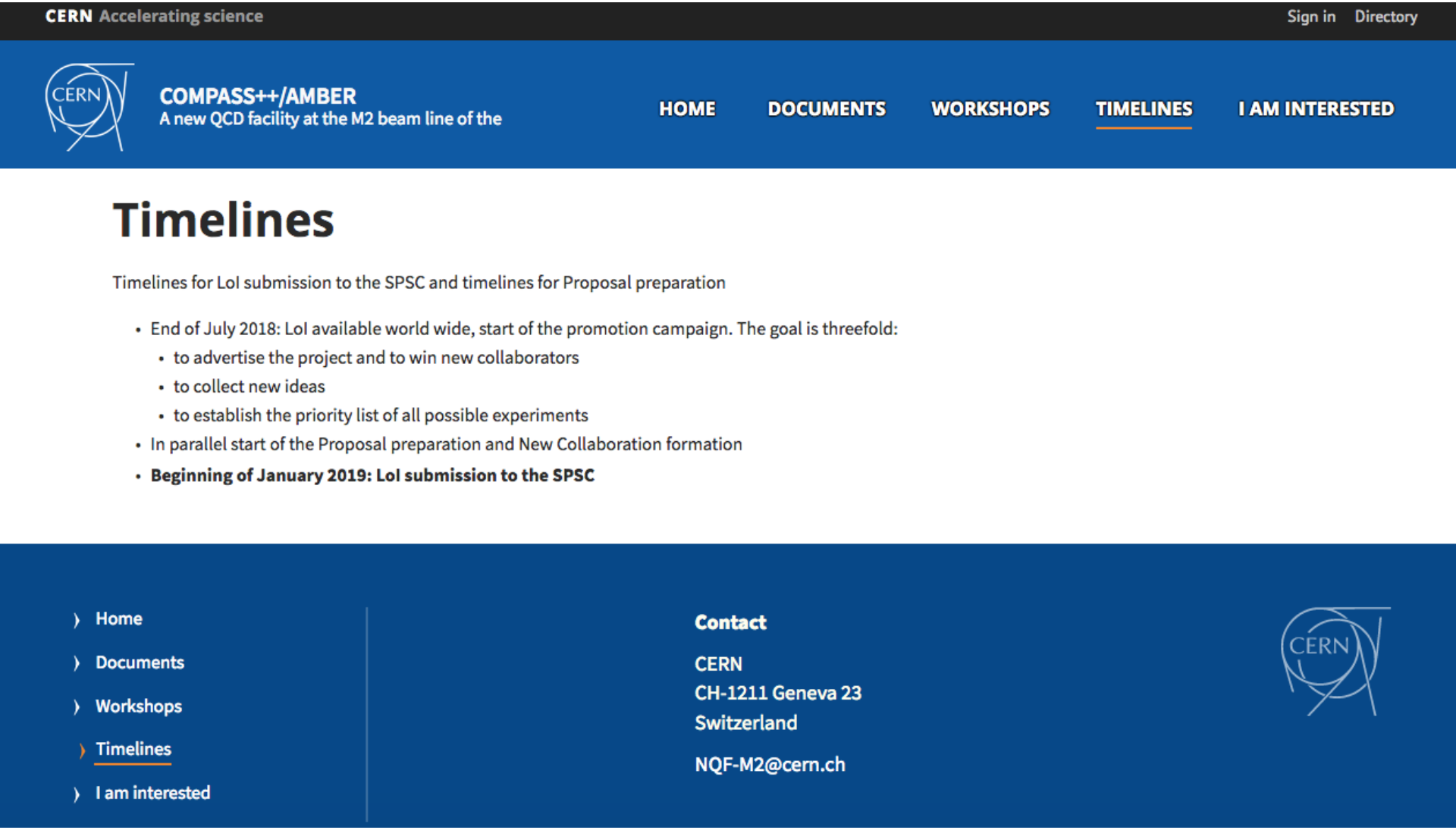
    13. 6. 2018 - 14. 6. 2018, CERN, https://indico.cern.ch/event/706741/

    - O. Denisov for the LoI group
      https://indico.cern.ch/event/706741/contributions/2938769/attachments/1668114/2674995/PBC_2018_06_14_Oleg.pdf

7. **IWHSS'18 Workshop**

    19. 3. 2018 - 21. 3. 2018, Bonn, Germany, https://indico.cern.ch/event/658983/

New CERN SPS based QCD facility
COMPASS++/AMBER
Web page III: https://nqf-m2.web.cern.ch/



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COMPASS++/AMBER
A new QCD facility at the M2 beam line of the

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Timelines

Timelines for LoI submission to the SPSC and timelines for Proposal preparation

- End of July 2018: LoI available world wide, start of the promotion campaign. The goal is threefold:
  - to advertise the project and to win new collaborators
  - to collect new ideas
  - to establish the priority list of all possible experiments
- In parallel start of the Proposal preparation and New Collaboration formation
- **Beginning of January 2019: LoI submission to the SPSC**

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Contact

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A NQF (COMPASS++/AMBER) summary for ESPP

A New QCD Facility at the M2 beam line of the CERN SPS

Document for the 2020 update of the European Strategy for Particle Physics

Abstract

This document summarises the physics interest, sensitivity reach and competitiveness of a future general-purpose fixed-target facility for Particle Physics research. Based upon the versatile M2 beam line of the CERN SPS, a great variety of measurements is proposed to address fundamental issues of Quantum Chromodynamics. In phase-1 of the project, operating with muons a complementary result on the average charged proton radius will be obtained and the elusive General Parton Distribution function E can be accessed, operating with pions the quark structure of the pion will be revealed, operating with antiprotons completely new results in the search of exotic XYZ states are expected, and operating with protons the antiproton production cross section will be measured as important input for future Dark Matter searches. Upgrading the M2 beam line in phase-2 of the project will provide unrivalled radio-frequency separated high-intensity and high-energy beams. Operating with kaons the virgin field of high-precision strange-meson spectroscopy becomes accessible, the Primakoff process will be used for a first measurement of the kaon polarisability, and the Drell-Yan process opens access to the

A NQF at SPS CERN LoI

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

arXiv 1808.00848

January 12, 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],

LoI content: Physics

Contents

The content of the LoI has been reported at several PBC meetings in 2016, 2017 and 2018.

10 projects for the moment, at first stage we are going to use available hadron/muon beam, at the second – RF separated kaon and antiproton beam.

All beams we are going to use are unique worldwide

LoI content: Instrumentation

It is difficult to give exact cost estimate right now: it stays in the range 10-20 MCHF

Summary table – beam requirements

Program	Physics Goals	Beam Energy [GeV]	Beam Intensity [s^{-1}]	Trigger Rate [kHz]	Beam Type	Target	Earliest start time, duration	Hardware Additions
μp elastic scattering	Precision proton-radius measurement	100	$4 \cdot 10^6$	100	$\mu^\pm$	high-pr. H2	2022 1 year	active TPC SciFi trigger silicon veto
Hard exclusive reactions	GPD E	160	10^7	10	$\mu^\pm$	$NH_3^\uparrow$	2022 2 years	recoil silicon, modified PT magnet
Input for DMS	$\overline{p}$ production cross-section	20-280	$5 \cdot 10^5$	25	p	LH2, LHe	2022 1 month	LHe target
$\overline{p}$-induced Spectroscopy	Heavy quark exotics	12, 20	$5 \cdot 10^7$	25	$\overline{p}$	LH2	2022 2 years	target spectr.: 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 det.
Primakoff (RF)	Kaon polarizi-bility & pion life time	~100	$5 \cdot 10^6$	> 10	K^-	Ni	n/e 2026 1 year	
Prompt Photons (RF)	Meson gluon PDFs	≥ 100	$5 \cdot 10^6$	10-100	$K^\pm$ $\pi^\pm$	LH2, Ni	n/e 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 5: Requirements for future programs at the M2 beam line after 2021. Standard muon beams are in blue, standard hadron beams in green, and RF-separated hadron beams in red.

Two stages program:

First stage (shorter term) – existing extracted beams
Second stage (longer term) – RF-separated extracted kaon and antiproton beams

Shorter term 2021/22 ÷~ 2026/28 (N.B. 2019/20 and 2025/26 – LS2 and LS3) :

a.) Standard muon beam:
- 1. DVCS with trans. polarised proton target
- 2. Proton radius measurement in elastic muon proton scattering

b.) Standard hadron beam:
- 1. Unpolarised DY with various targets
- 2. Absolute cross-section measurements p + He -> pbar X
- 3. Hadron spectroscopy with antiproton beam

Longer term (New RF-separated beam will be ready ≥ 2026):

- 1. Hadron spectroscopy
- 2. Drell-Yan physics
- 3. Primakoff with kaon beam
- 4. Direct Photons with kaon beam

Community

All in All:

we have for the moment 15 new groups (wrt COMPASS II) signed the LoI, among them there are 5 groups form USA (Georgia State Uni., Los Alamos NL, Uni. Of Chicago, Uni. Of Michigan, Stony Brook Uni.).
In 2019 we expect some more USA groups (2-3) to join the project.

Apart of that we have 4 more new countries: Armenia (1), Belarus (1), China (2) and Kazakhstan (1), so we have widen our geography.

The total number of authors (PhD students and higher) is 267.

According to our experience in order to carry out the research program depicted in LoI the collaboration of 250-300 physicists would be adequate.

PBC QCD summary document

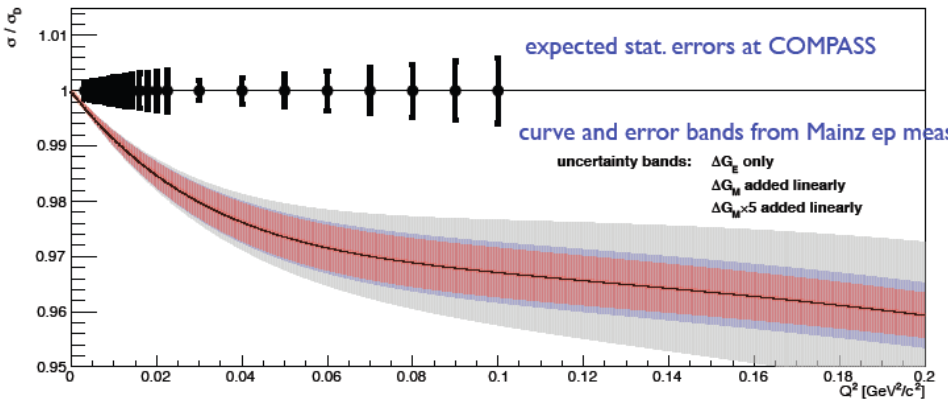
Contents

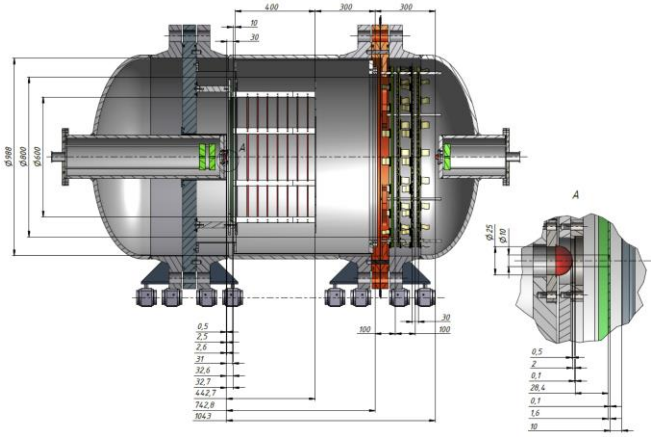
Proton Radius measurement

Physics case: determine the proton radius in high-energy muon-proton scattering

- elastic μp scattering at low Q^2
- key advantages over ep
  - measure electric form factor G_E, essentially no contribution from magnetic one G_M (high E)
  - much smaller QED rad. corr. (muon mass)
- remains: theory uncertainty from fitting the form factor slope

- 100 GeV SPS M2 muon beam
- high-pressure hydrogen TPC active-target cell (PNPI development)
- measure cross-section shape over broad Q2 range 10^{-4}…10^{-1}
- fit from 10^{-3} … $2x10^{-2}$ the proton radius (slope of electric form factor)

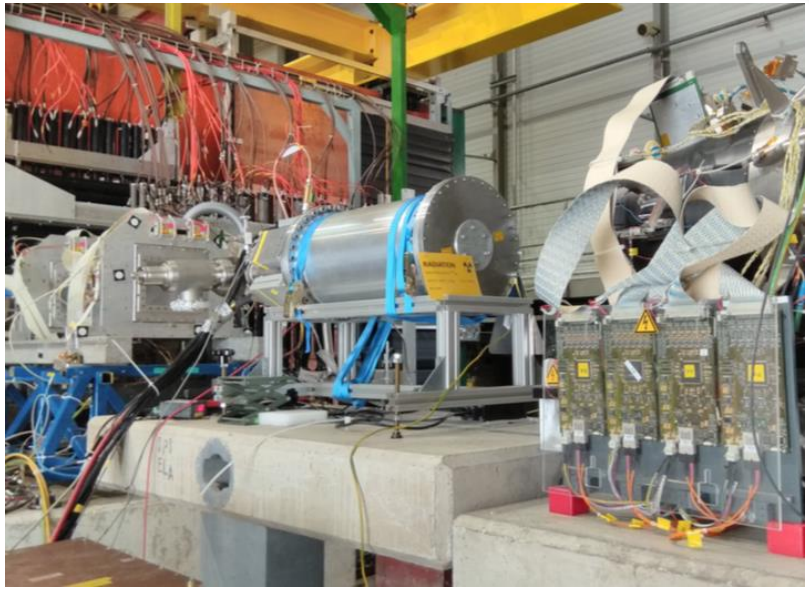


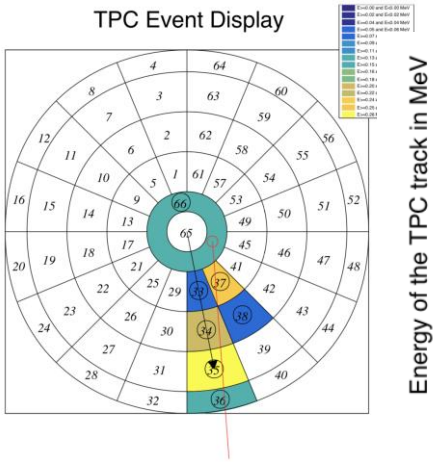


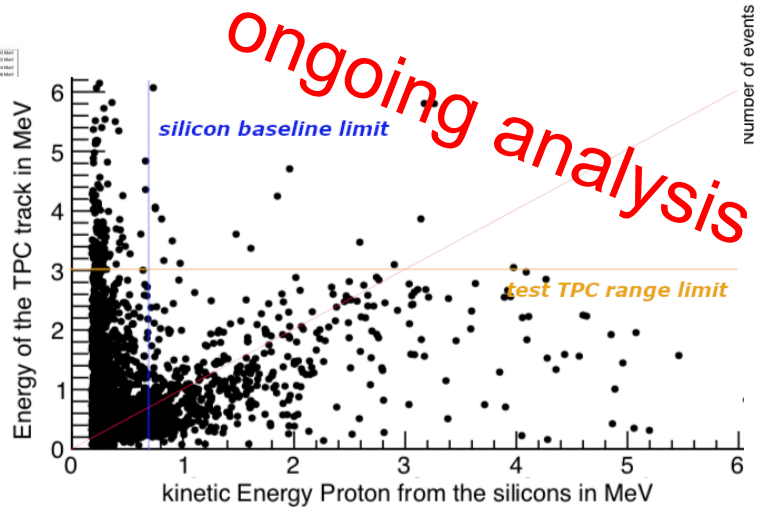
Test in 2018 for Proton Radius measurement

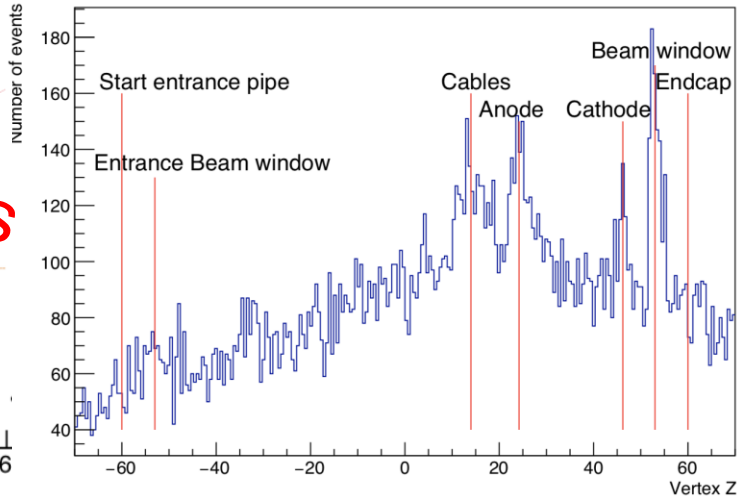
Test setup during 2018 DY run downstream COMPASS, check

- TPC operation in muon beam ✓
- vertex reconstruction with silicon telescopes ✓
- coincidence detection of scattered muon and recoiling proton ✓









Test in 2018 for Proton Radius measurement

- demonstrated the measurement principle employing the active TPC and silicon detectors
- Q^2 range was limited by geometry
  - lower limit ca. 3×10^{-3} due to short SI detector baseline and high beam energy (ca. 180 GeV)
  - upper limit ca. 6×10^{-3} due to proton range in 8bar H_2
- observed event rate and structure roughly within expectations, calibrations and data analysis ongoing

a hot physics topic – this experiment should run in 2022 at M2 and needs soon CERN support statement for realization

Timelines

- LoI is submitted to SPSC, would be very useful to have a statement and encouragement to proceed with Proposal preparation

- The intention is to have a first draft of the Proposal ready by the end of 2019

- Proposal submission to SPSC – May 2019

SUMMARY

1. Existing SPS extracted hadron/lepton beams are unique world-wide, RF separated beam option is unique as well

2. Physics case for the new QCD facility is there

3. Community is there

4. Work on full scale Proposal is started

Thank you!