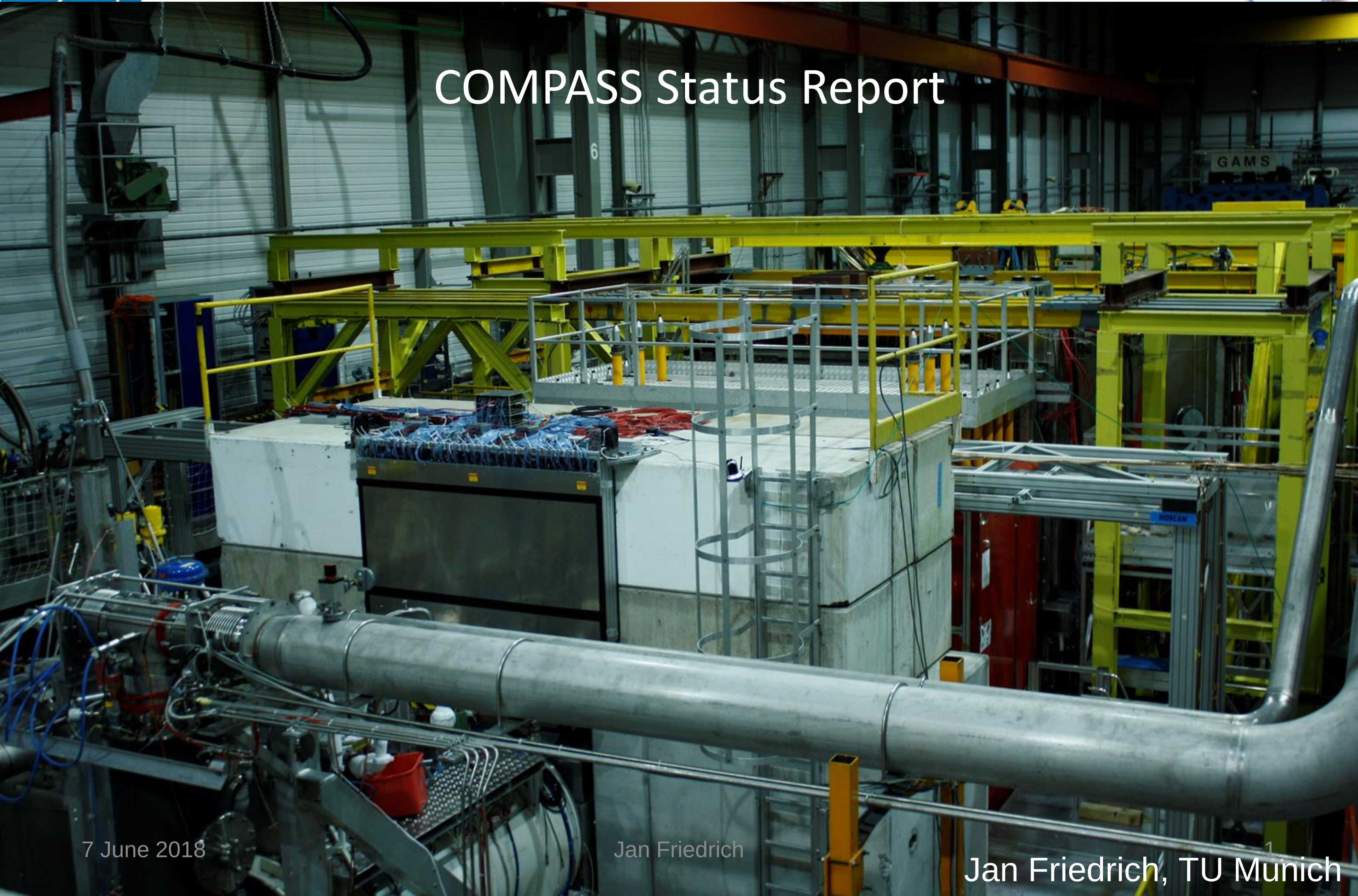
SPSC meeting
7. June 2018

COMPASS Status Report



Jan Friedrich, TU Munich

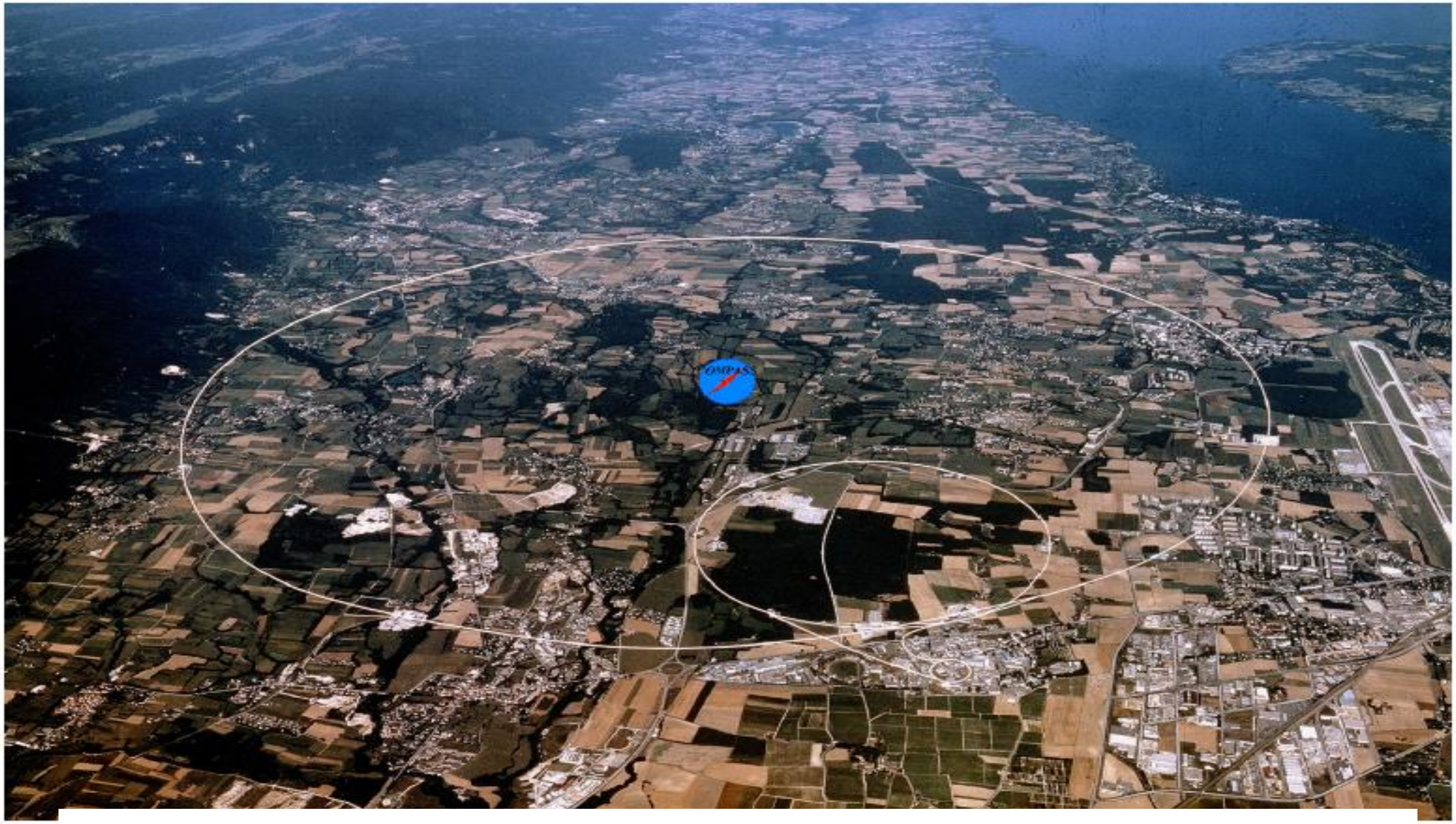
Outline

1. **Hadron structure and excited states**
   - Light quark spectroscopy – news on resonance parameters
   - ChPT test: chiral anomaly
2. **Nucleon structure with muon beam**
   - Longitudinal / transverse spin structure functions
   - Proposal for transversely polarised deuteron run in 2021
   - Multiplicities
3. **DVCS and DVMP**
   - Exclusive ω and GPDs (2012 pilot run)
   - DVCS – analysis progress for 2016+2017
4. **Drell-Yan**
   - First polarised Drell-Yan experiment 2015
   - Status of 2018 run
5. **First test results for proton radius measurement**
6. **New hardware and technology**
7. **LoI – fixed target experiment at SPS M2 line beyond 2020**
8. **Summary**

skipped parts: X(3872)-like state, Lambda production, part of azimuthal asymmetries etc……(cf. Annual Report)

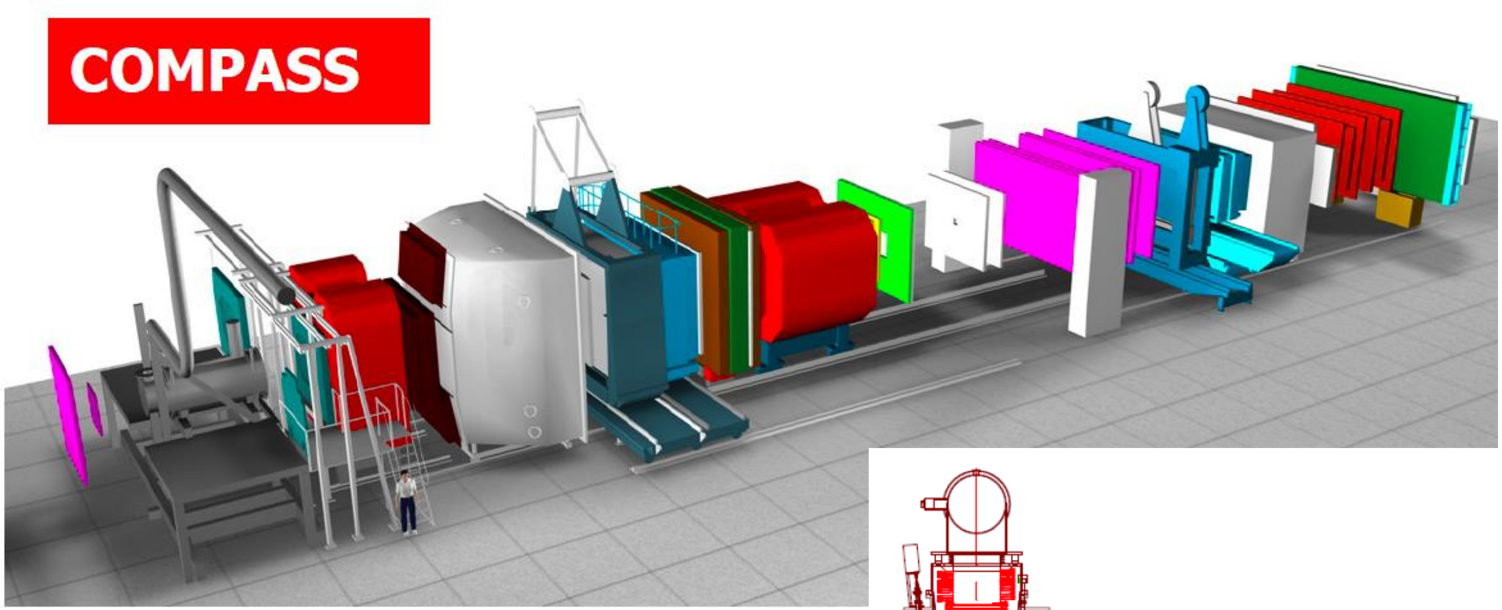
COMPASS QCD facility at CERN (SPS)

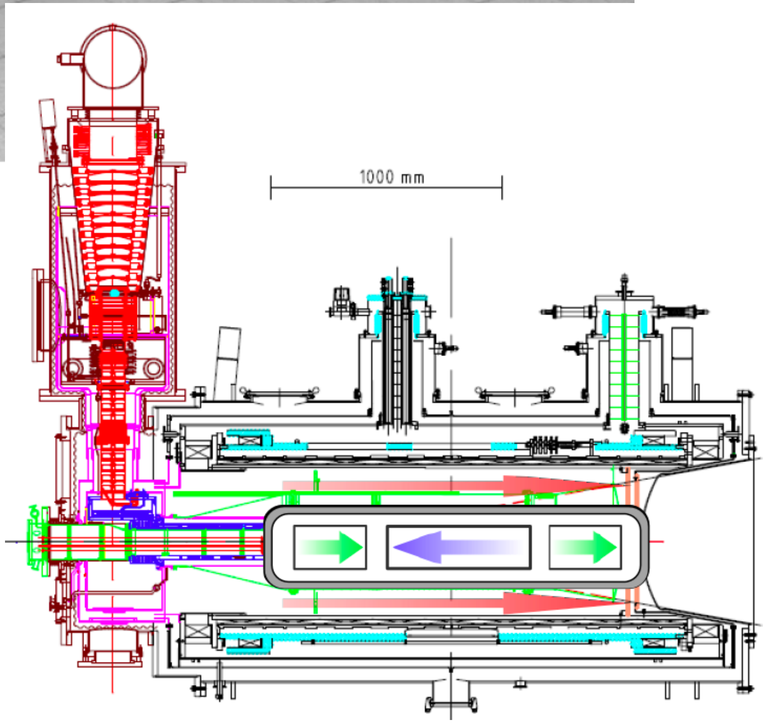
COmmon Muon Proton Apparatus for Structure and Spectroscopy



~240 physicists, 12 countries + CERN, 24 institutions

COMPASS Spectrometer at SPS M2 beam line (CERN)

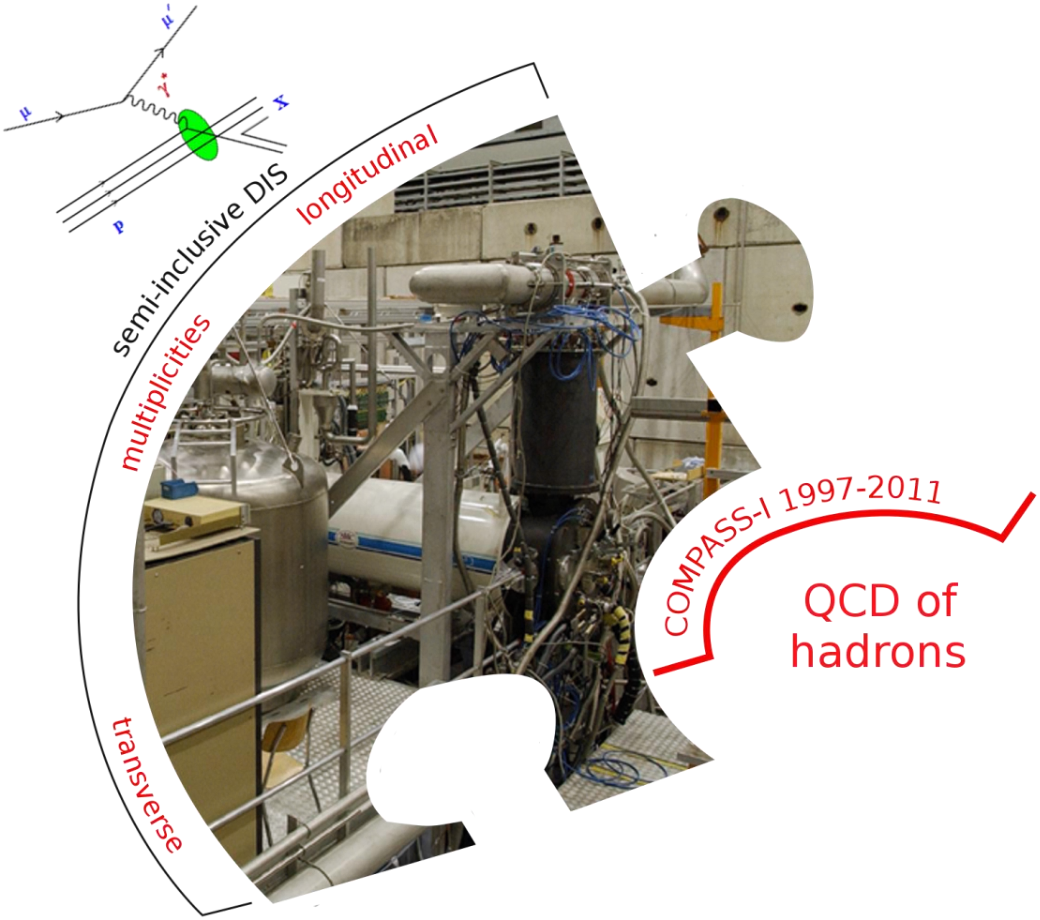




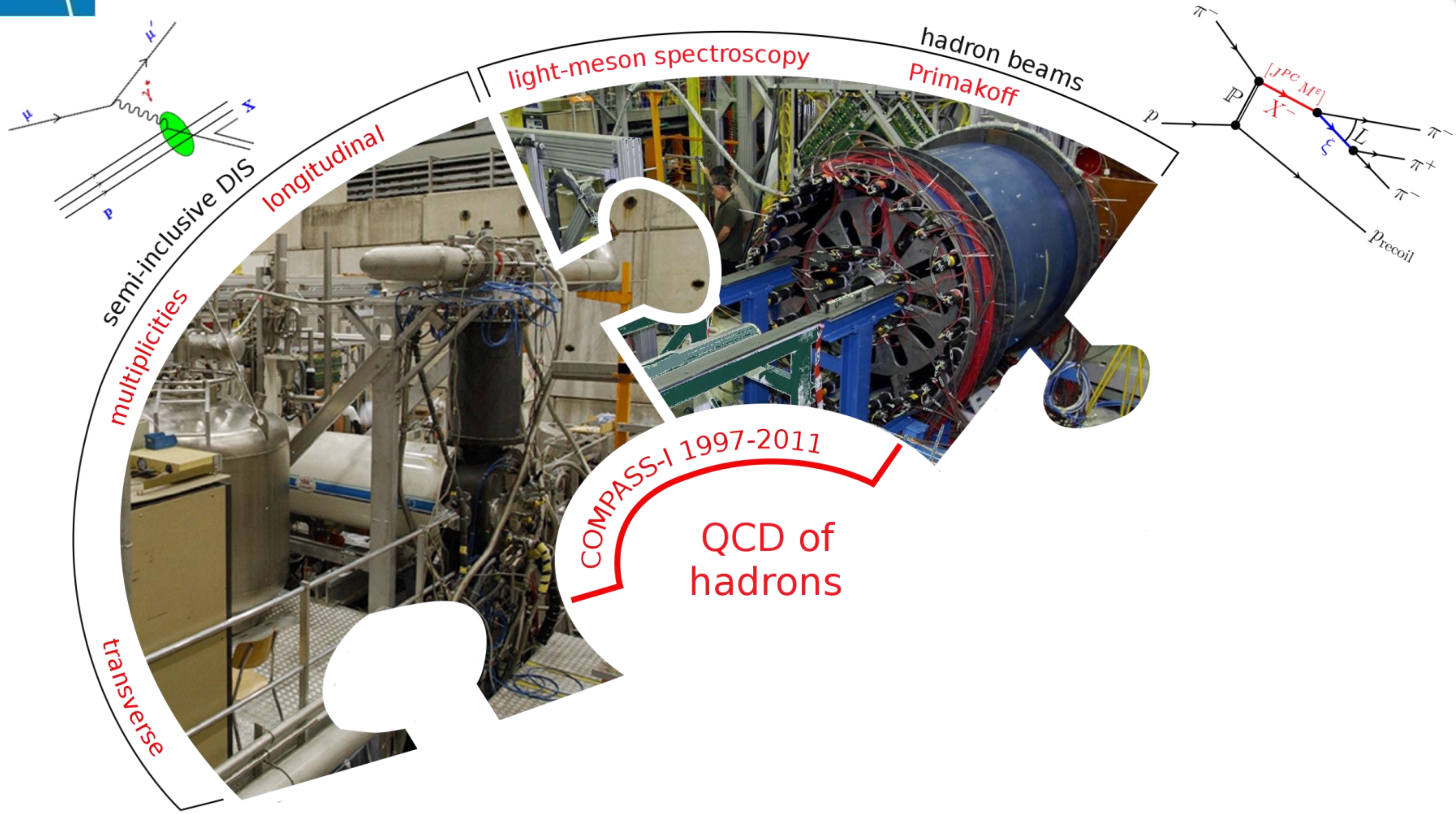
Versatile apparatus to investigate QCD:
Two-stage COMPASS Spectrometer

1. Muon, electron and hadron beams with momenta 20-250 GeV and intensities up to 10^8 particles per second
2. Solid-state polarised (NH_3 or ^6LiD), liquid hydrogen and nuclear targets
3. Powerful tracking (350 planes) and PID systems (Muon Walls, Calorimeters, RICH)

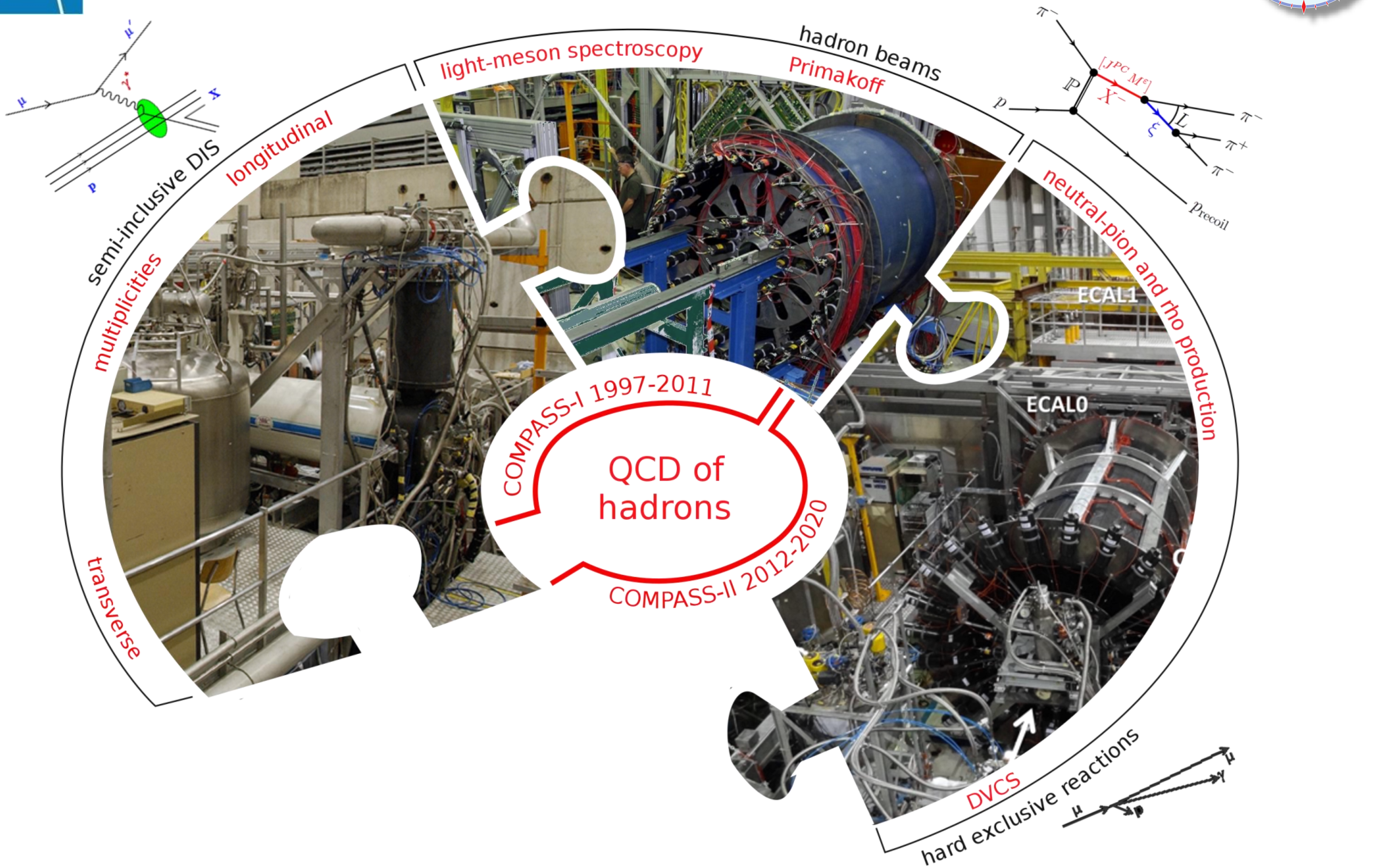
COMPASS QCD facility at SPS M2 beam line (CERN) secondary hadron and lepton beams



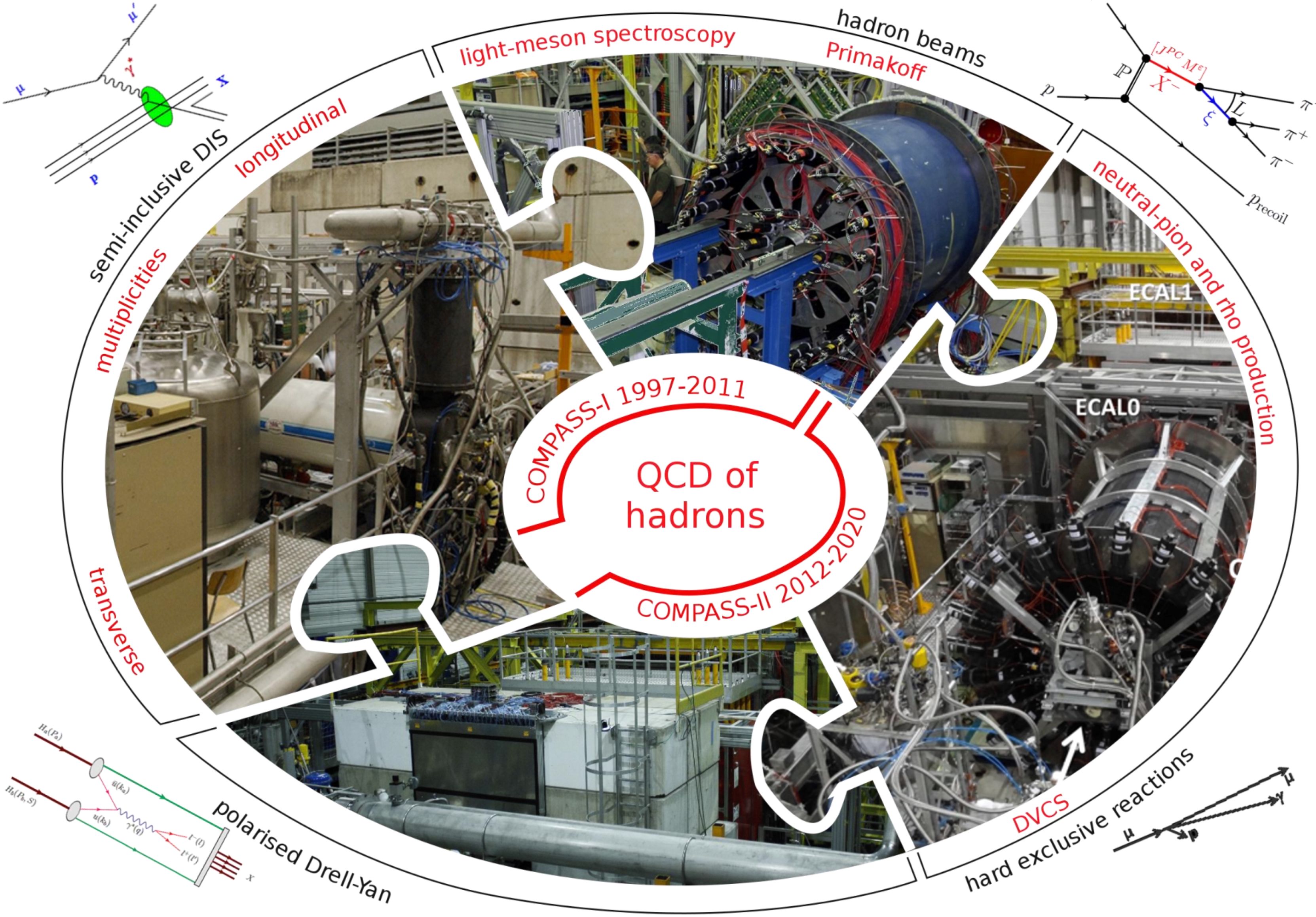
COMPASS QCD facility at SPS M2 beam line (CERN) secondary hadron and lepton beams



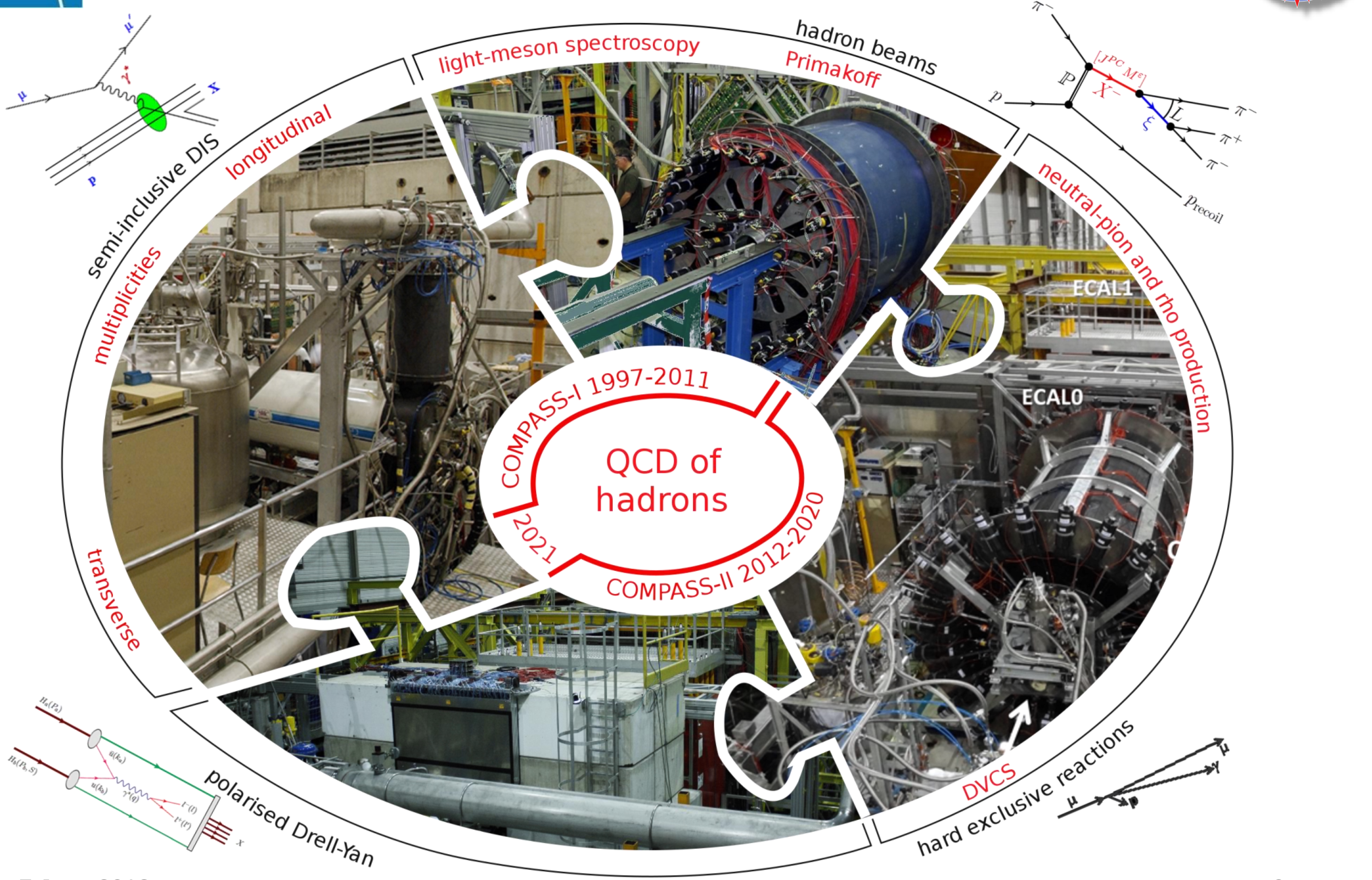
COMPASS QCD facility at SPS M2 beam line (CERN) secondary hadron and lepton beams



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



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

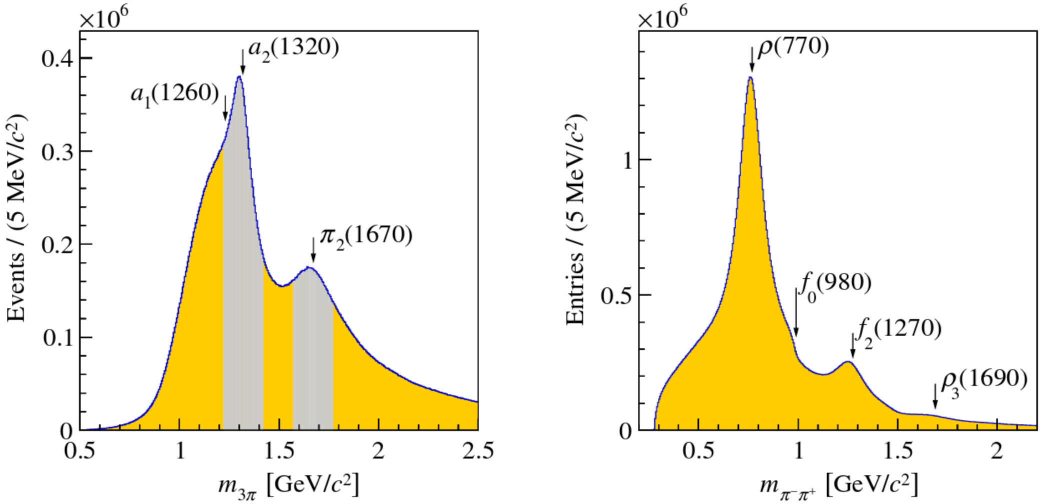


Physics with hadron beams: meson spectroscopy

main results

PHYSICAL REVIEW D **95**, 032004 (2017)

Resonance production and $\pi\pi$ S-wave in $\pi^- + p \rightarrow \pi^-\pi^-\pi^+ + p_{\mathrm{recoil}}$ at 190 GeV/c

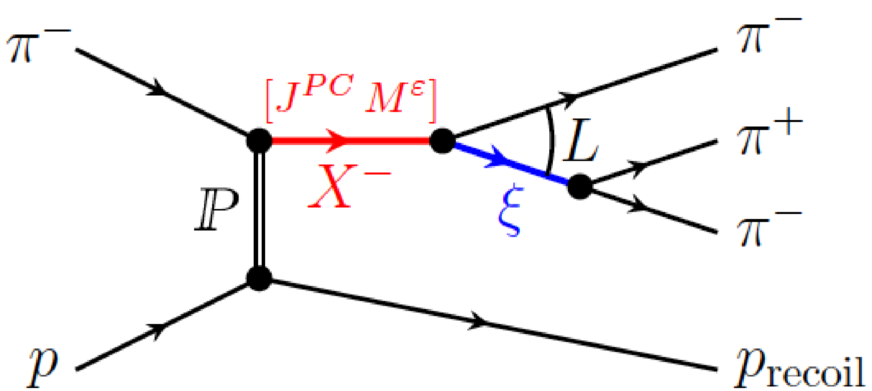


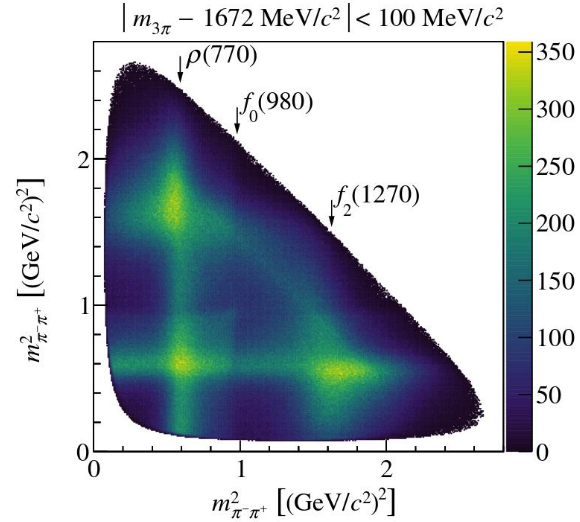
published in 2017: PRD 59 pages

2008-2009 data taking, 190 GeV/c hadron beam on a hydrogen target

3π data sample ~50 million events
10x to 100x previous experiments
allows for fine binning in masses and momentum transfer

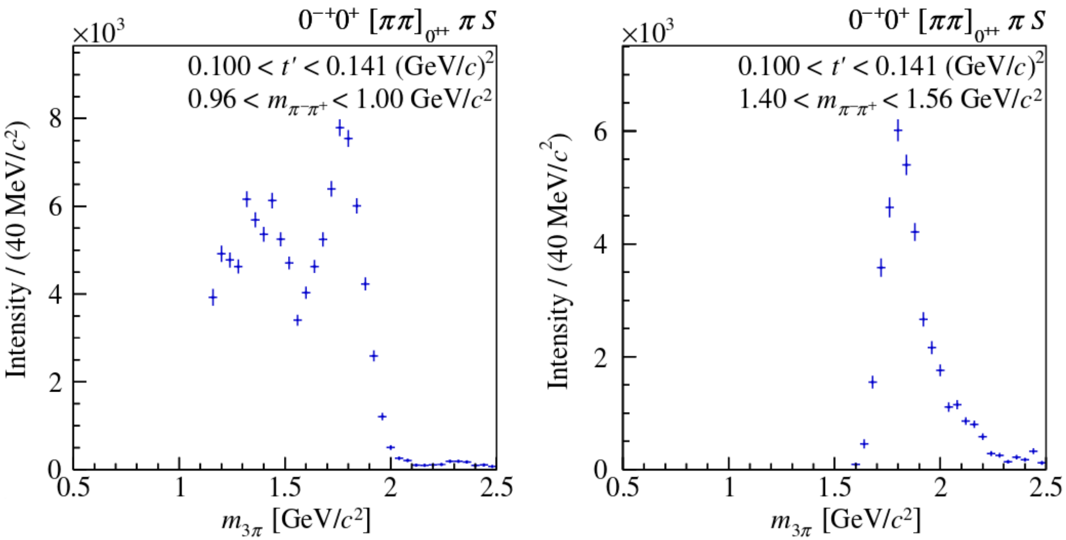
partial-wave analysis in *3π*-mass slices, detailed understanding of the *2π*-isobars





Physics with hadron beams: meson spectroscopy

main results

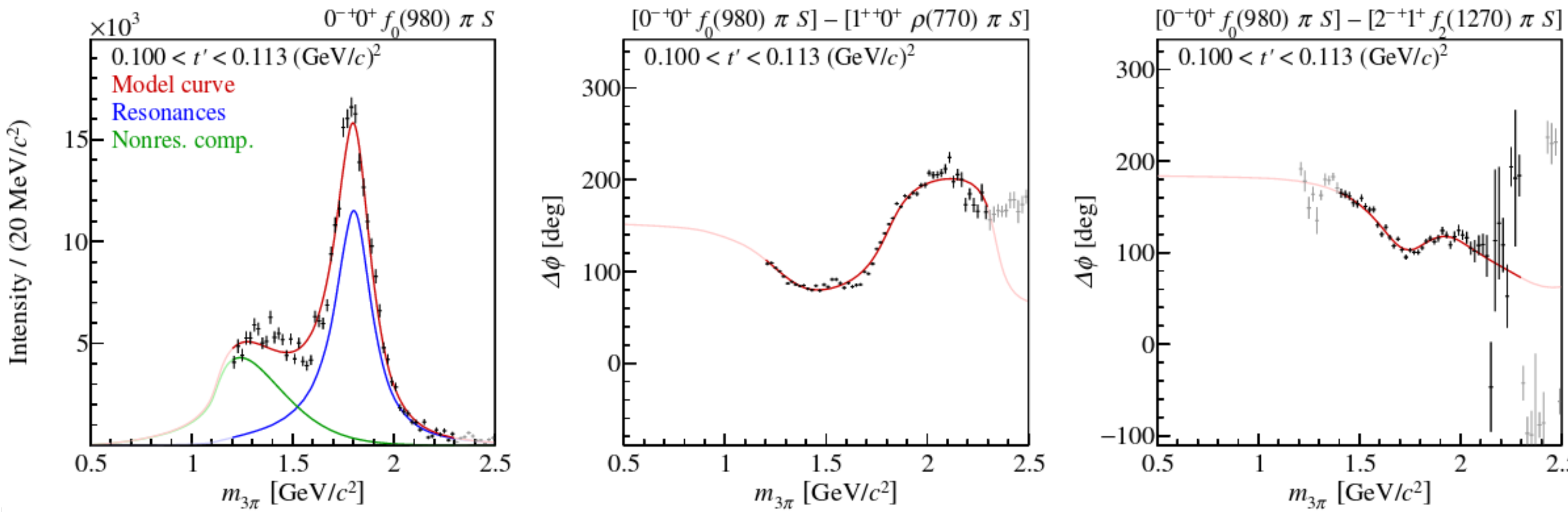


example: partial wave for *π(1800)*

investigation of 2π isobar structure reveals contributions from $f_0(980)$ and $f_0(1500)$

recently accepted: paper on partial-wave fits including 3π resonances, PRD 75 pages

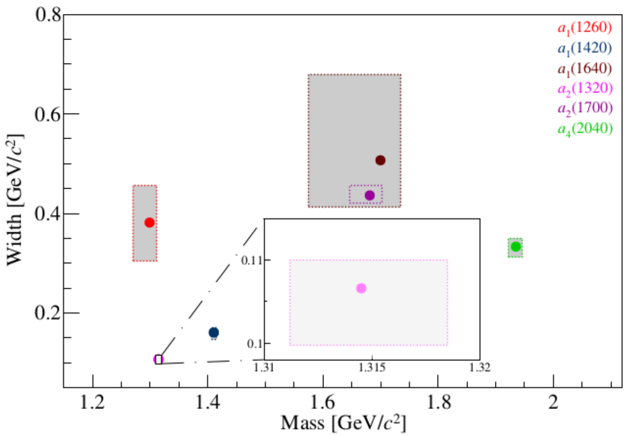
Light isovector resonances in $\pi^- p \to \pi^-\pi^-\pi^+ p$ at 190 GeV/c

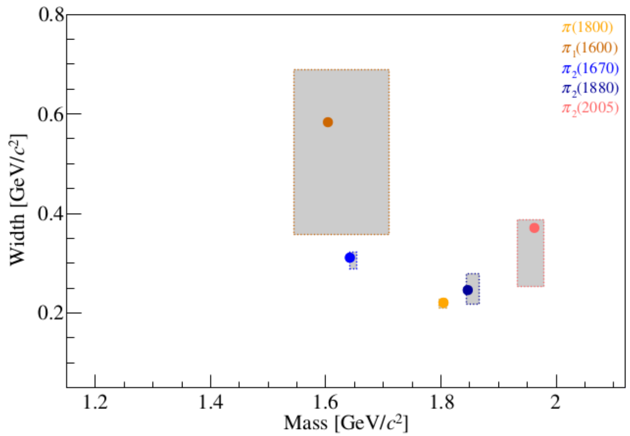


Physics with hadron beams: meson spectroscopy

main results

Light isovector resonances in $\pi^- p \rightarrow \pi^- \pi^- \pi^+ p$ at 190 GeV/c

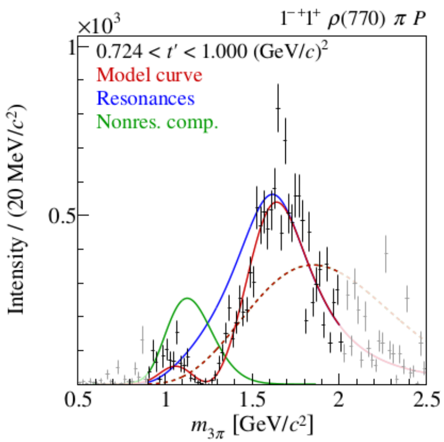


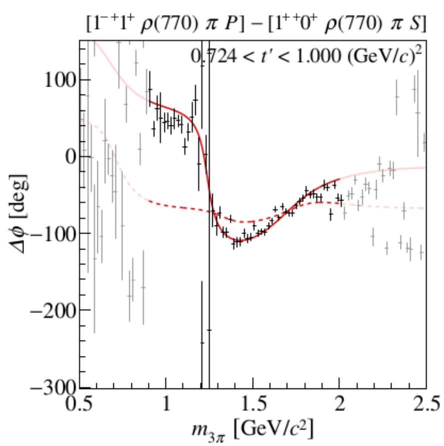


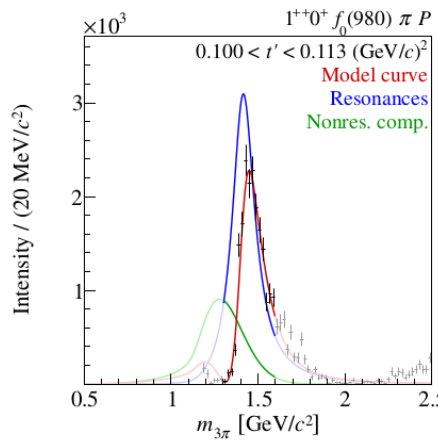
resonance parameters with unprecedented precision and systematic investigations:
6 a-like and 5 π-like states

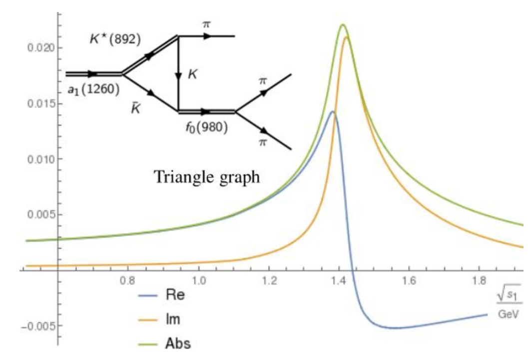
broad spin-exotic $\pi_1(1600)$

further investigations of the $a_1(1420)$ found by COMPASS: triangle amplitude consistent with Breit-Wigner







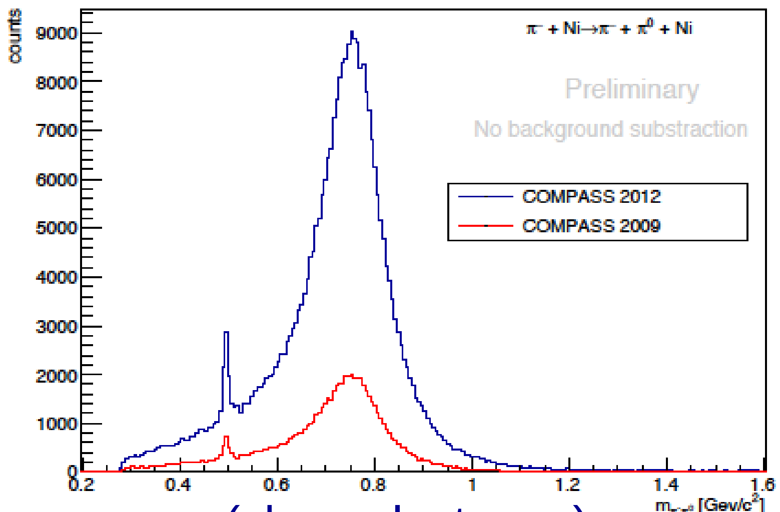


Measurement of chiral dynamics in reactions $\pi^- \gamma^{(*)} \rightarrow \pi^- (n\pi)$

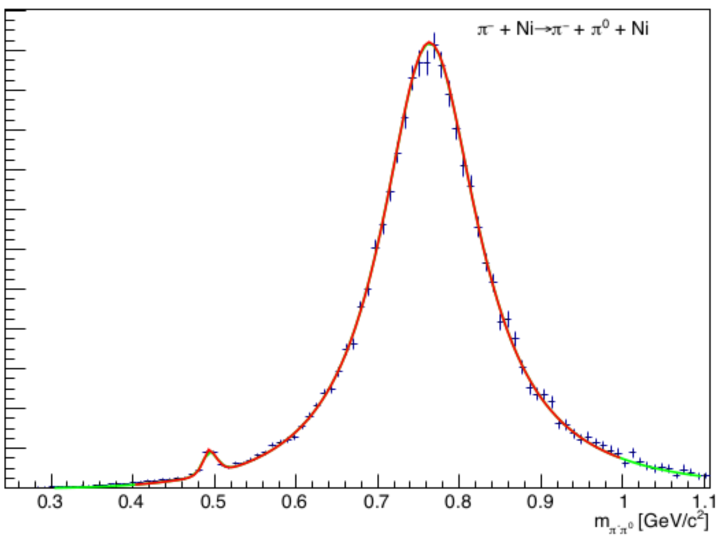
Primakoff data samples:

π^- -nucleus scattering at lowest momentum transfers ➔ $\pi^-\gamma$ reactions

$\pi^- \pi^0$ final state: low-energy part dominated by the chiral anomaly



(shown last year)

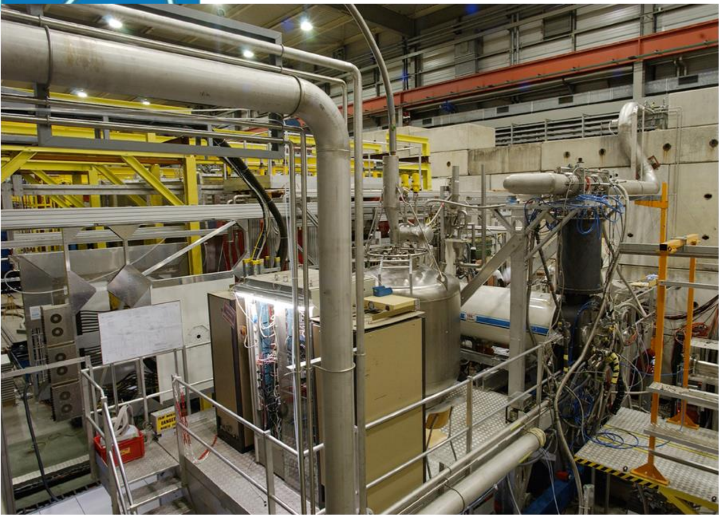


Analysis progress: background subtraction ($\pi^- \pi^0 \pi^0$)

fit to theory (M. Hoferichter *et al*, 2012)

under investigation: luminosity determination

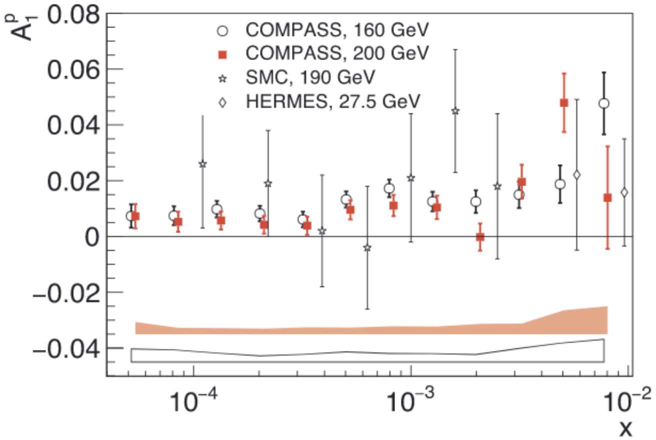
(SI)DIS longitudinal I – Final results

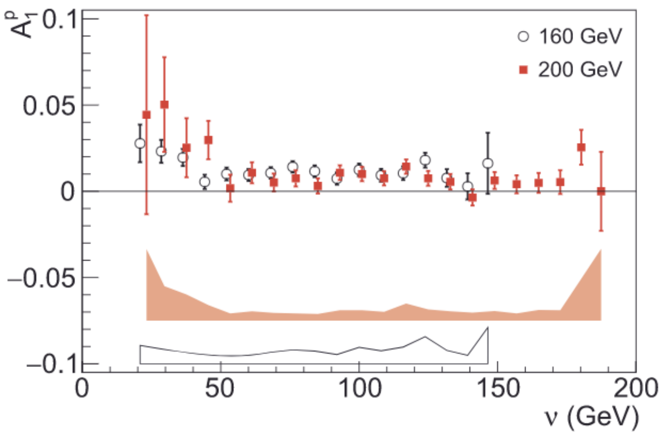


double-spin asymmetry A_1^d and longitudinal spin structure function g_1^d all-deuteron data PLB 769 (2017) 034. Together with the results on the proton spin structure function g_1^p, these results constitute the COMPASS legacy on the measurements of the g_1 structure function.

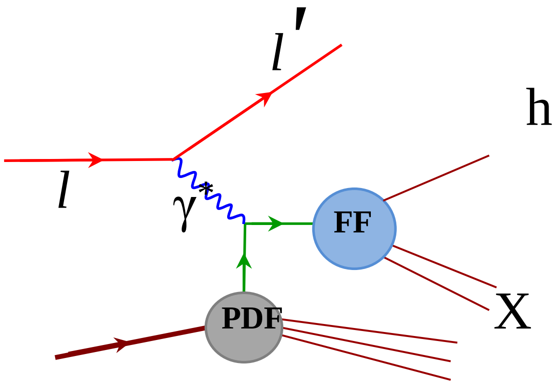
all-deuteron data $\Delta g/g$ final result
EPJC (2017) 209

Most recent: Longitudinal double-spin asymmetry A_1^p and spin-dependent structure function g_1^p of the proton at small values of x and Q^2, Phys. Lett. B 781 (2018) 464

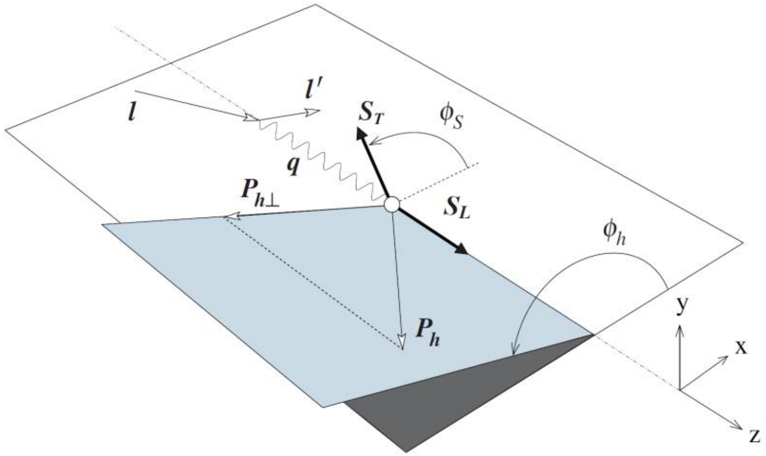




SIDIS transverse & longitudinal



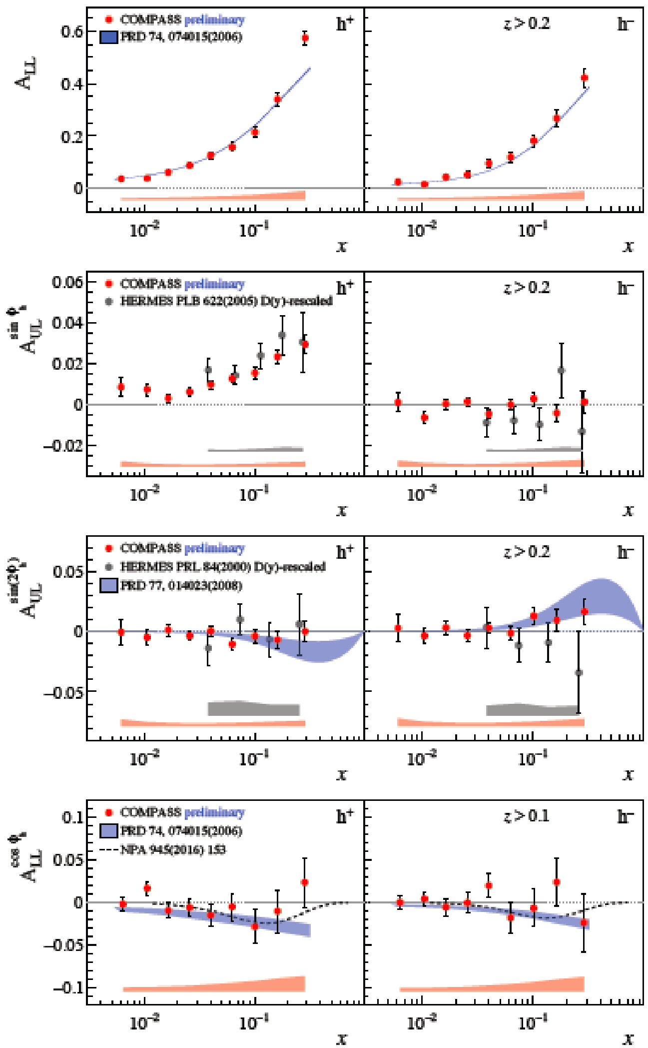
We continue to scrutinize polarised SIDIS data by studying various target-spin-dependent azimuthal asymmetries.
The general expression for polarised SIDIS cross-section contains 6 LO and 6 sub-leading asymmetries



LO LSA/TSA	twist-2: PDF ⊗ FF
$A_{UL}^{\sin(2\phi_h)}$	$h_{1L}^{\perp q} \otimes H_{1q}^{\perp h}$
A_{LL}	$g_{1L}^{q} \otimes D_{1q}^{h}$
$A_{UT}^{\sin(\phi_h-\phi_S)}$	$f_{1T}^{\perp q} \otimes D_{1q}^{h}$
$A_{UT}^{\sin(\phi_h+\phi_S-\pi)}$	$h_{1}^{q} \otimes H_{1q}^{\perp h}$
$A_{UT}^{\sin(3\phi_h-\phi_S)}$	$h_{1T}^{\perp q} \otimes H_{1q}^{\perp h}$
$A_{LT}^{\cos(\phi_h-\phi_S)}$	$g_{1T}^{q} \otimes D_{1q}^{h}$

SIDIS longitudinal

longitudinal target-spin-dependent asymmetries (LSA)



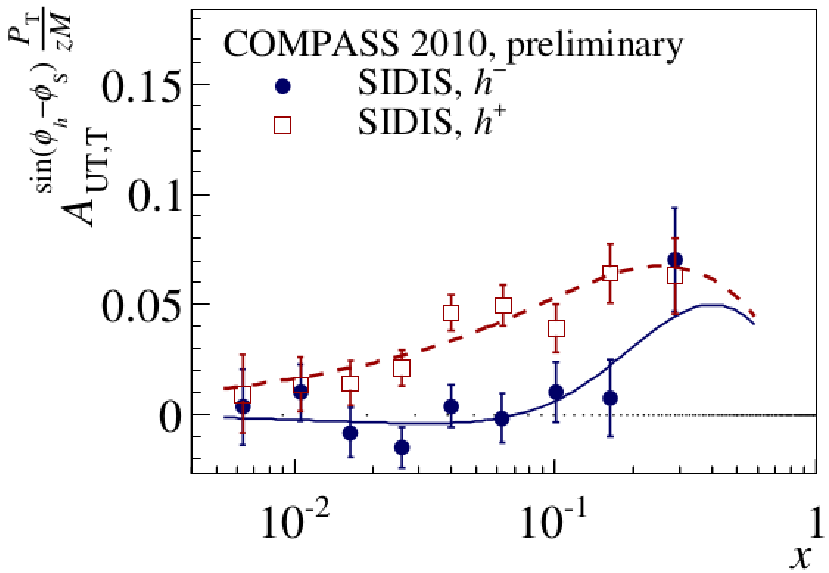
final results for the longitudinally polarised proton target (2007 and 2011 Runs).

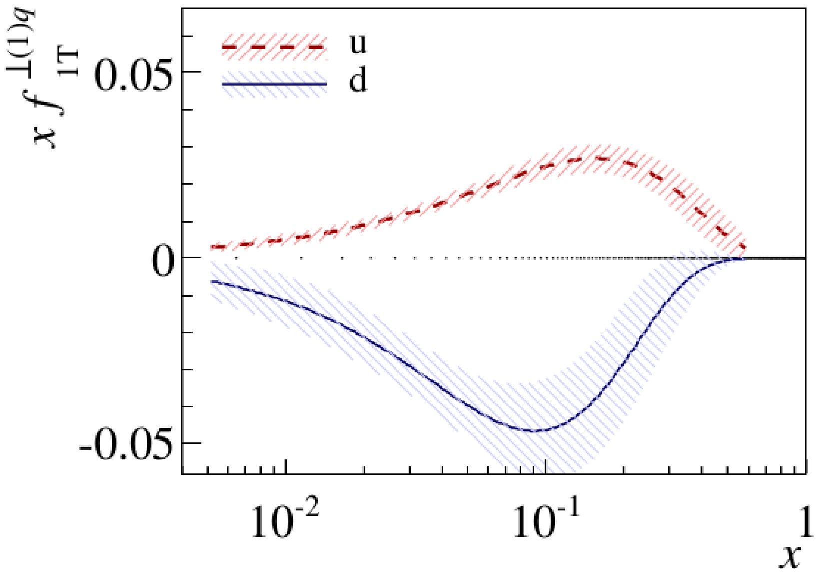
error bars: statistical uncertainties
systematic uncertainties indicated by colour bands

compared to the similar studies presented by HERMES and CLAS, our results are characterised by an unprecedented precision, covering a much wider kinematic range

SIDIS transverse

New approach continued: weighted asymmetries





$$A_{Siv}^{(p_T^h/zM)}(x,z) = 2\frac{\sum_q e_q^2 f_{1T}^{\perp(1)\,q}(x)\cdot D_1^q(z)}{\sum_q e_q^2 f_1^q(x)\cdot D_1^q(z)},$$

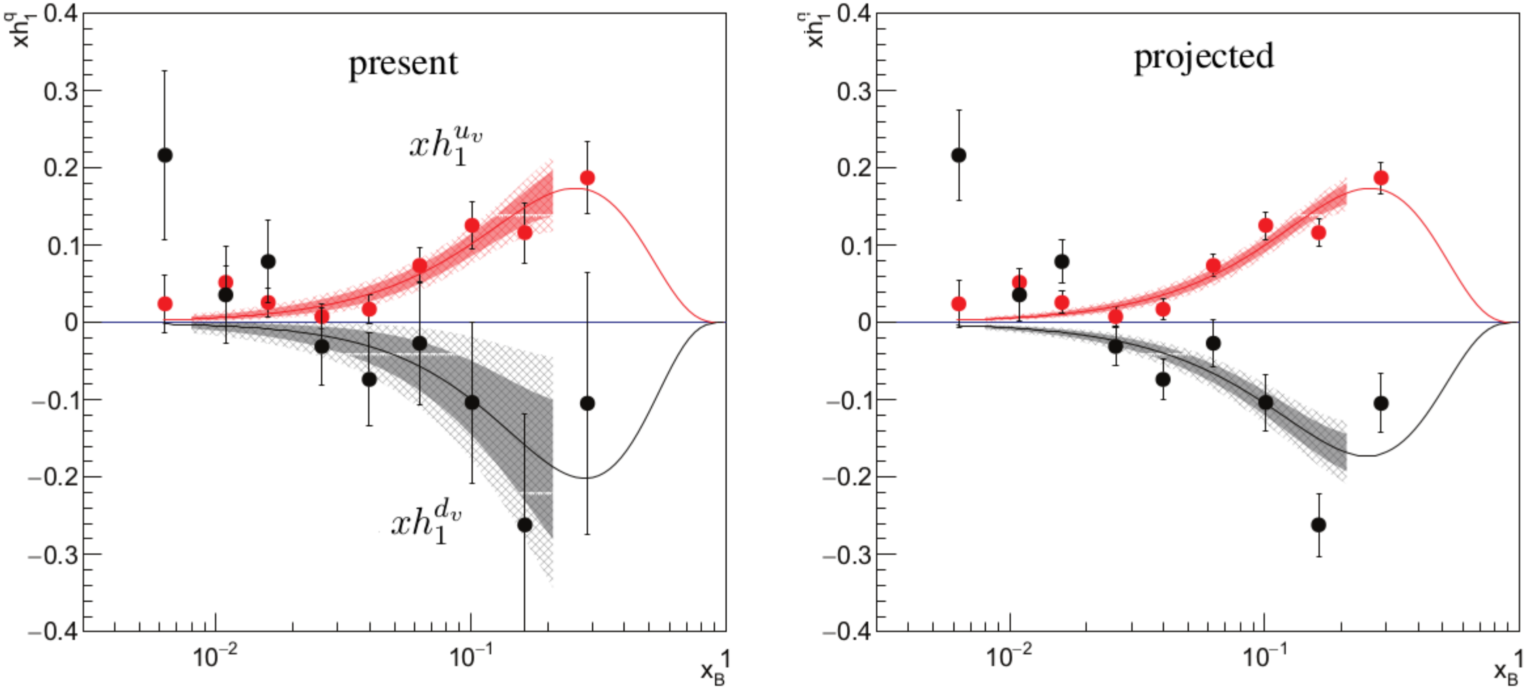
Important: large statistics, good acceptance. Allows to extract first moment of Sivers

$$f_{1T}^{\perp(1)}(x,Q^2) = \int d^2k_T \frac{k_T^2}{2M^2} f_{1T}^{\perp}(x,k_T,Q^2).$$

Work in progress:
analogous analysis for weight P_T/M

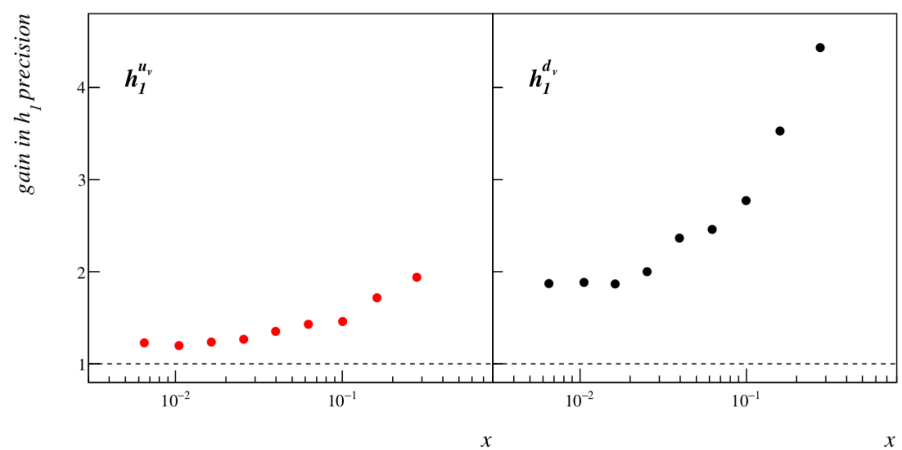
SIDIS transverse

Proposal for 2021: transverse-deuteron run



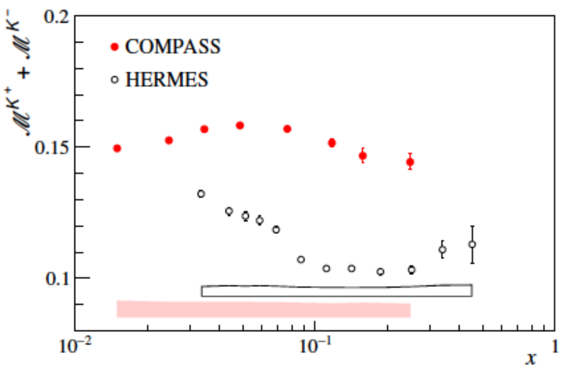
For a precise determination of the Collins functions for u and d, COMPASS is currently lacking an adequate data set with transversely polarised deuteron target.

recently recommended by SPSC for approval

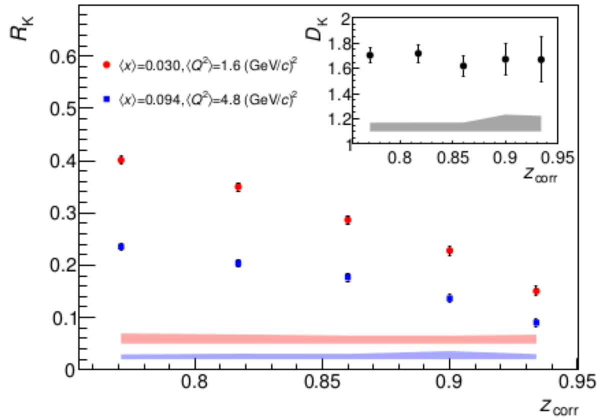


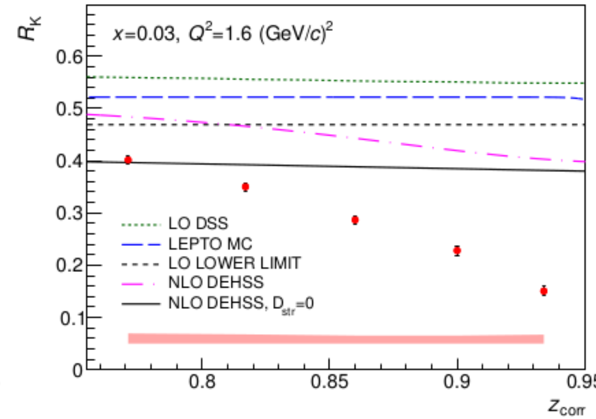
SIDIS (kaon) multiplicities

Charged kaon multiplicities (2006 160 GeV ^{6}LiD) – published in PLB 767 (2017) 133
The 3-dimensional data set (x, y and z) ➔ important input for NLO pQCD analyses of the world data in terms of FFs.

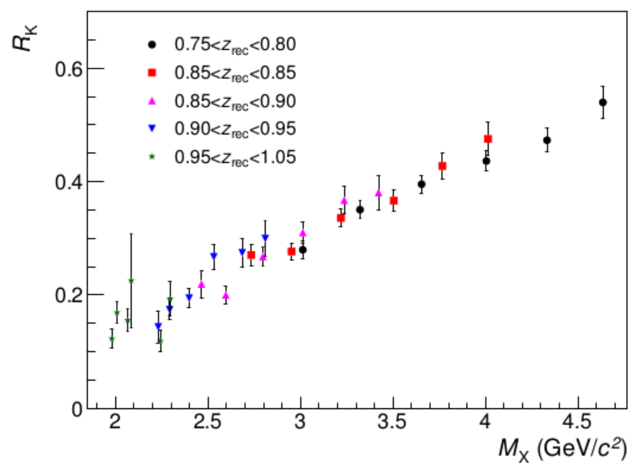


HERMES and COMPASS data are in tension
Can not be explained only by the different Q^2 range

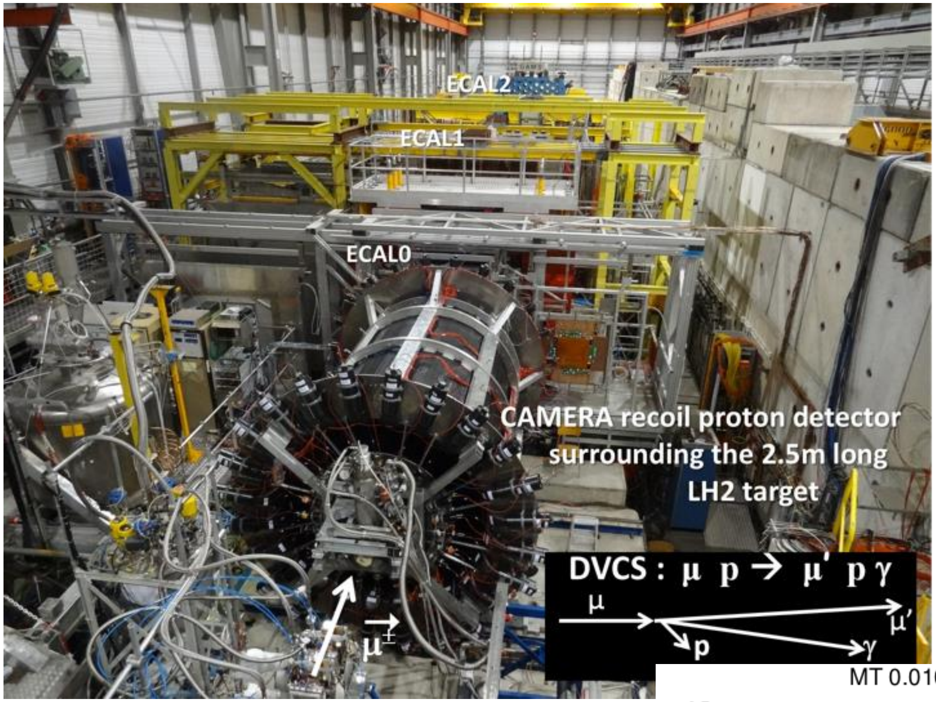




results on the kaon multiplicity ratio K^-/K^+, at high z, 0.75 < z < 1: our data go far beyond the LO upper boundary value of (u+d)/(ū+đ) calculated at x=0.03 using MSTW08L as well as beyond the actual predictions of the ratio using Lund model or LO DSS fit. Recent finding: dependence on M_X



Deeply Virtual Compton Scattering – analysis progress for 2016/17 data

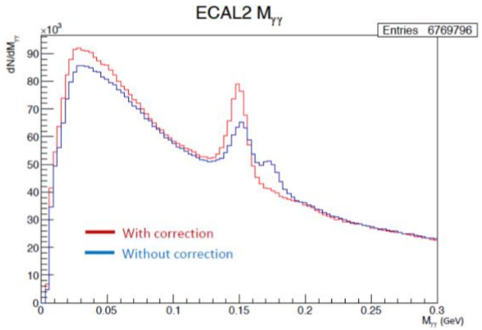


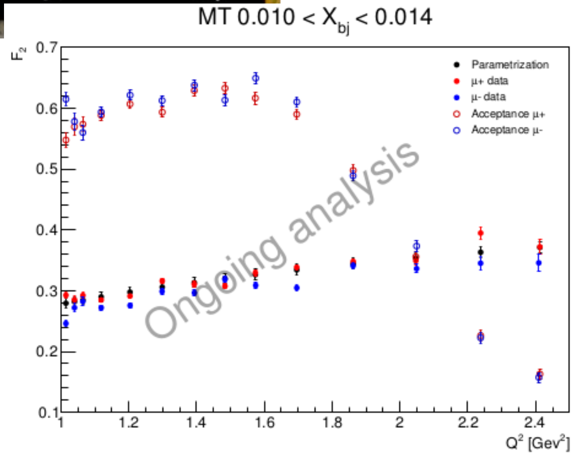
2012 pilot run: μ^+/μ^- data taken with different intensities by a factor of about 2.5; luminosity determination became only reliable on the level of 10%

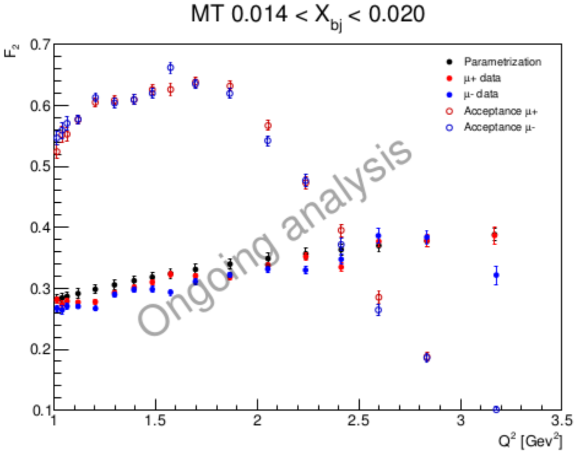
➔ measurement in 2016/17 with equalized intensity

F_2 and μ^+/μ^- comparison 2016: close to a few %

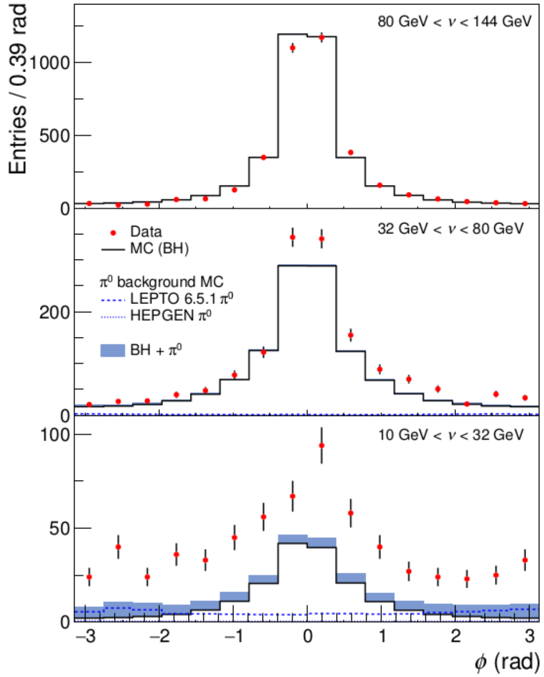
refinement of calibration:





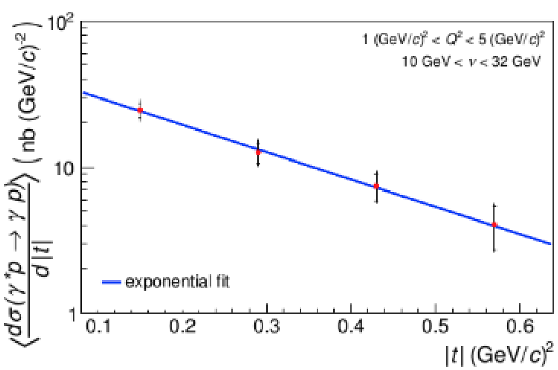


Generalised Parton Distributions – analysis of 2012 data

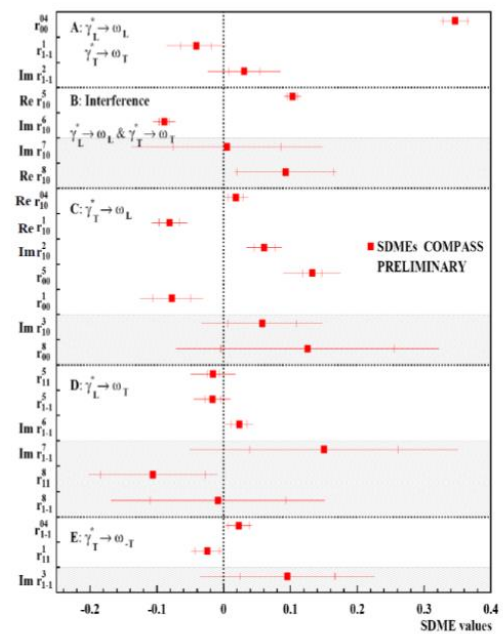


average transverse extension of partons in the proton probed by DVCS (subm. PRL):

$$\sqrt{\langle r_\perp^2 \rangle} = (0.58 \ \pm \ 0.04_{\rm stat} \ {}^{+\,0.01}_{-\,0.02}\big|_{\rm sys}) \ \text{fm}.$$



SDME via exclusive ω production:



Deeply Virtual Compton Scattering – achieved statistics in 2012 and 2016/17

2016 - 130 days - mainly 2 spills of 4.8 s every 36 s						
	I_{proton} on T6 per spill	I_μ on IonCH per spill	Nb of spills	DAQ life time	Veto life time	Nb of collected muons
μ^+	$100 \cdot 10^{11}$ $70 \cdot 10^{11}$	$7.6 \cdot 10^7$ $5.3 \cdot 10^7$	135527 18592	0.93	0.95	$10.0 \cdot 10^{12}$
μ^-	$100 \cdot 10^{11}$ $70 \cdot 10^{11}$	$6.3 \cdot 10^7$ $4.4 \cdot 10^7$	143848 28255	0.94	0.95	$9.2 \cdot 10^{12}$

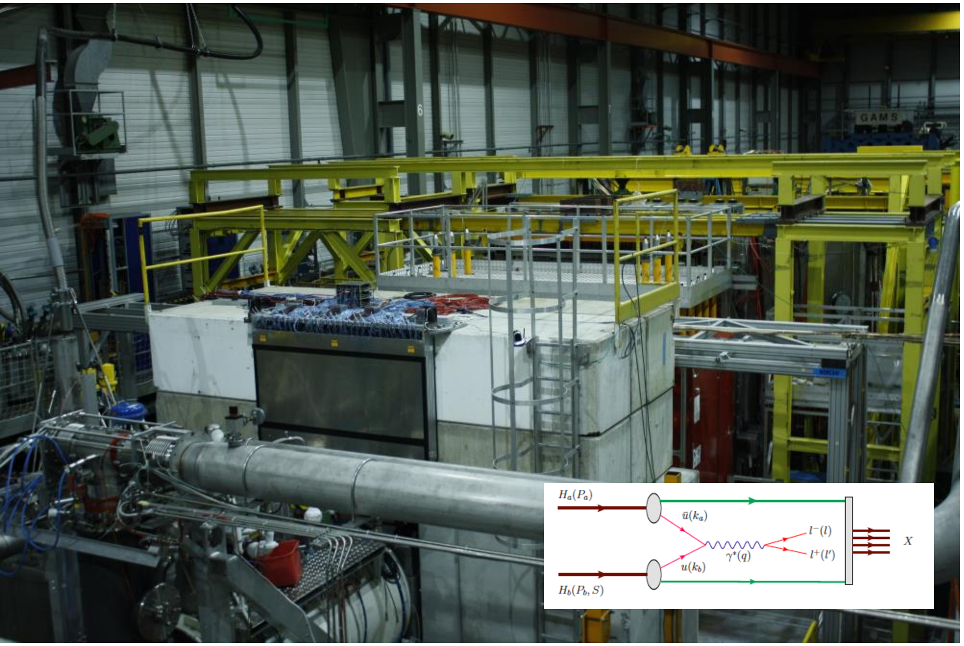
2017 - 130 days - mainly 2 spills of 4.8 s every 36 s						
	I_{proton} on T6 per spill	I_μ on IonCH per spill	Nb of spills	DAQ life time	Veto life time	Nb of collected muons
μ^+	$150 \cdot 10^{11}$	$12.5 \cdot 10^7$	168000	0.91	0.93	$17.8 \cdot 10^{12}$
μ^-	$150 \cdot 10^{11}$	$10.5 \cdot 10^7$	195000	0.91	0.93	$17.3 \cdot 10^{12}$

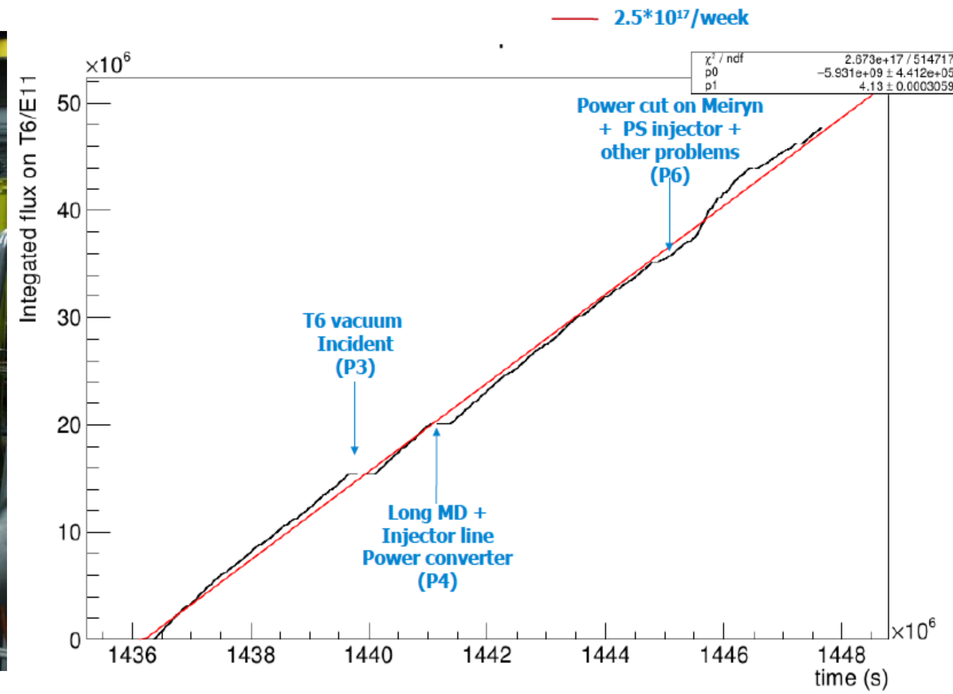
2012 - 30 days - 1 spill of 9.6 s every 48 s						
	I_{proton} on T6 per spill	I_μ on IonCH per spill	Nb of spills	DAQ life time	Veto life time	Nb of used muons
μ^+	$250 \cdot 10^{11}$	$50. \cdot 10^7$		0.84	0.73	$1.87 \cdot 10^{12}$
μ^-	$250 \cdot 10^{11}$	$17.5 \cdot 10^7$		0.94	0.89	$2.33 \cdot 10^{12}$

Assuming data quality in 2016/17 with 80% “good spills”, we collected in 2016/17 about a factor of 10 more statistics compared to 2012

COMPASS Drell-Yan Run 2015 results

First ever polarised Drell-Yan data





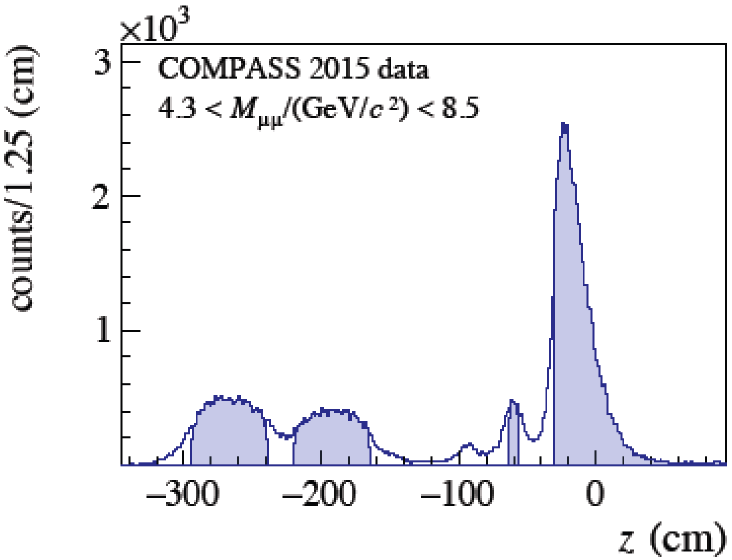
9 periods are collected (~2 weeks long each, polarisation is inverted after first week)

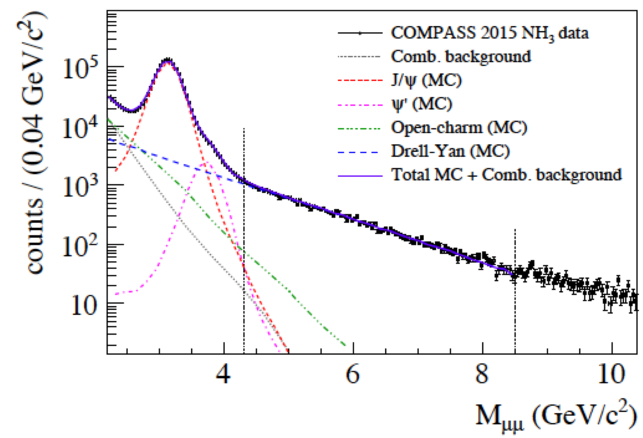
Good machine performance: on average 84%
Good spectrometer availability: ~80%

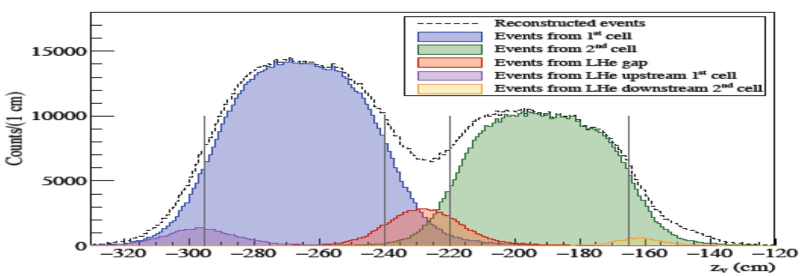
COMPASS Drell-Yan Run 2015 results

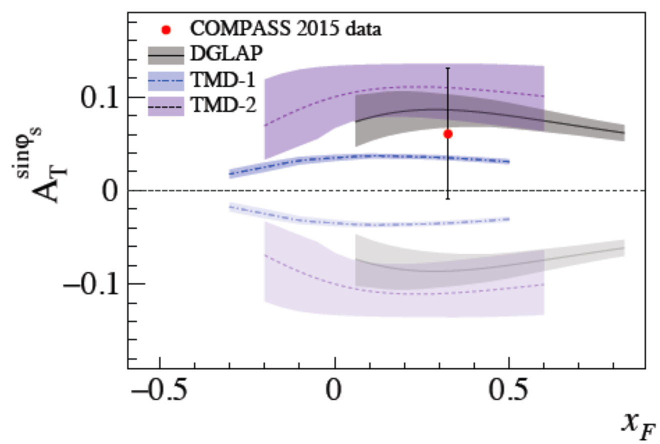
PRL **119,** 112002 (2017) PHYSICAL REVIEW LETTERS week ending 15 SEPTEMBER 2017

First Measurement of Transverse-Spin-Dependent Azimuthal Asymmetries in the Drell-Yan Process









Total number of J/ψ (NH_3) is **~ 1.500.000**

Total number of HM DY (4.3 GeV/$c^2 < M_{\mu\mu} <$ 8.5 GeV/ c^2) (NH_3) is **~35.000**

2018 Drell-Yan Run

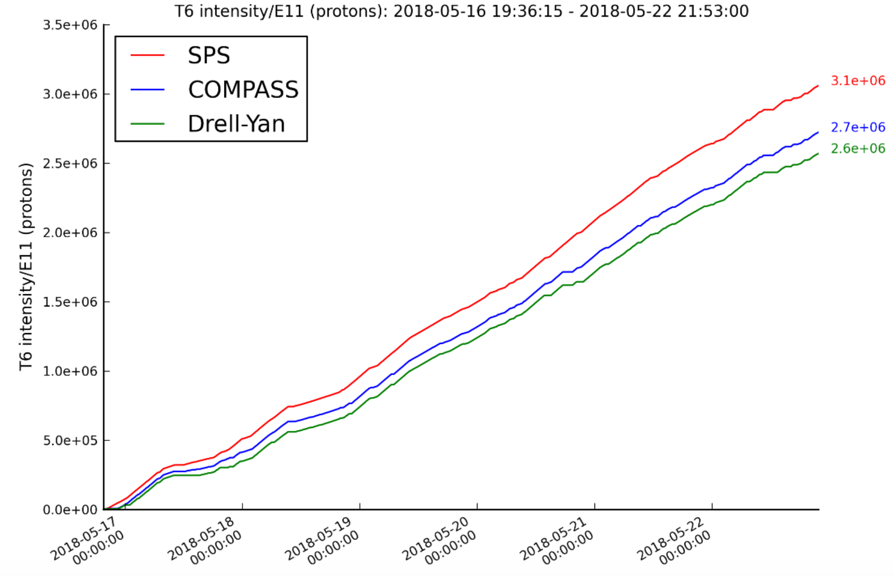
One of the main goals of the polarised Drell-Yan program at COMPASS is the unambiguous verification of the Sivers asymmetry sign change.

Improvements with respect to 2015 data taking:

1. Beam telescope (additional SciFi station, 11 planes vs 8 in 2015)
2. CEDARS: fast MAPMT and new read out chain – high rate capable system
3. Polarised Target – new field rotation procedure + extensive commissioning period
4. Better tuned trigger system
5. New radiation protection (additional wrt 2015)

Data Taking for physics was started May 17th, in spite of 6 weeks long delay on commissioning because of the cooling water tower refurbishment.

Unfortunately no beam since Wednesday May 30th for NA (SPS – NA extraction line Problem)



Polarised Target performance in 2018

1. After long and dense commissioning period first polarisation is achieved on April 24th
2. After 40 hours of polarisation (May 8th) : -82.7 % (up), +81.3 % (down)
3. New field rotation procedure < 0.10 % loss compared to 0.50% in 2015

Polarization after 26h in 2015 and 2018

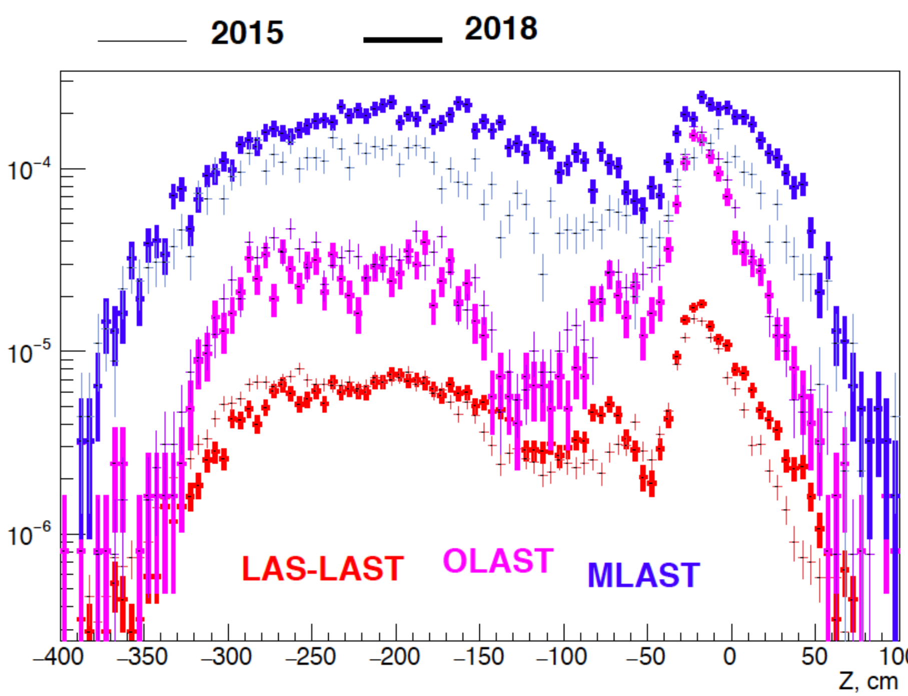
	Upstream Cell	Downstream Cell
Positive Polarization	+ 75.3 % + 75.0 %	+73.2 % + 78.2 %
Negative Polarization	- 73.5 % - 80.3 %	-72.2 % -79.4 %

Relaxation time with beam in 2015 and 2018

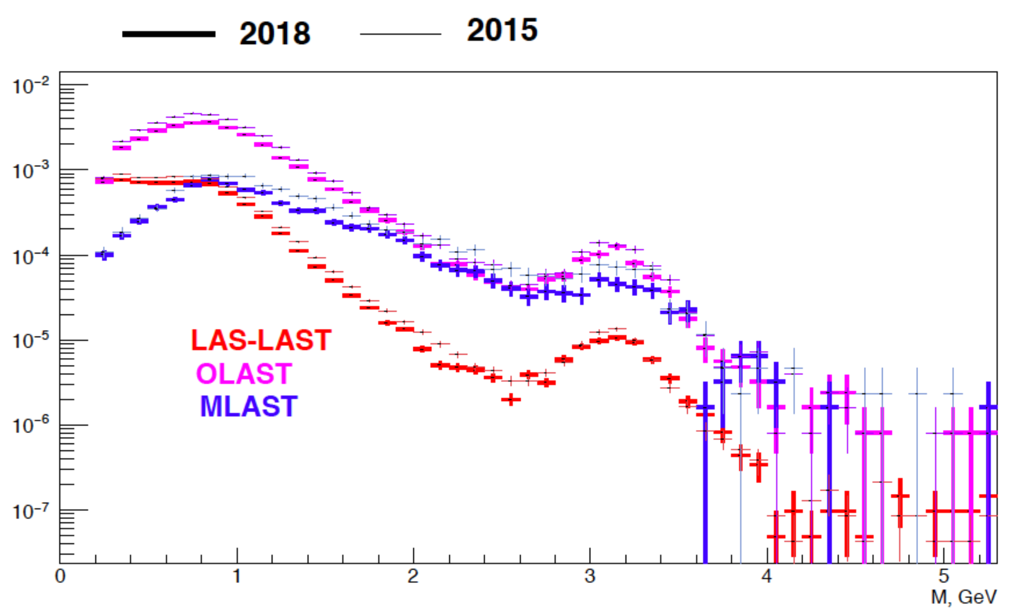
	Upstream Cell	Downstream Cell
Positive Polarization	~ 1200 h ~ 1500 h	~ 1000 h ~ 1500 h
Negative Polarization	~ 900 h ~ 1300 h	~ 700 h ~ 1100 h

Express-Analysis 2018

Rates of dimuons with M>2.5 GeV (normalized to the trigger rates)



Rates of dimuons in target (normalized to the trigger rates)

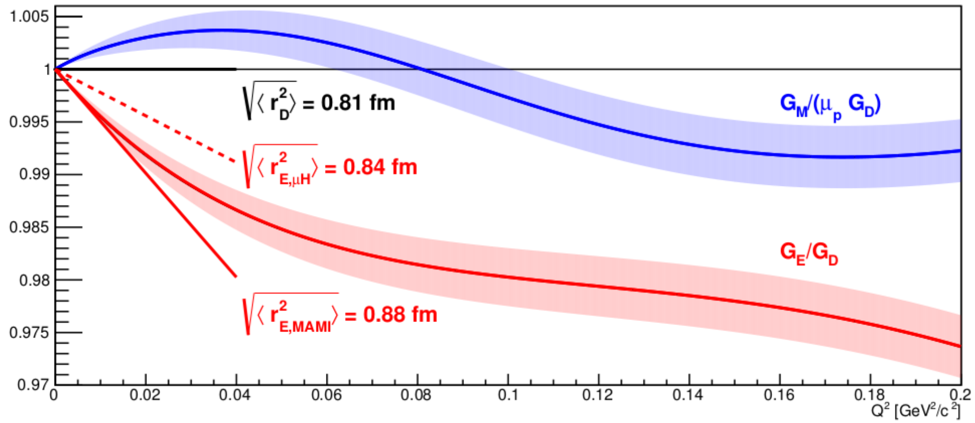


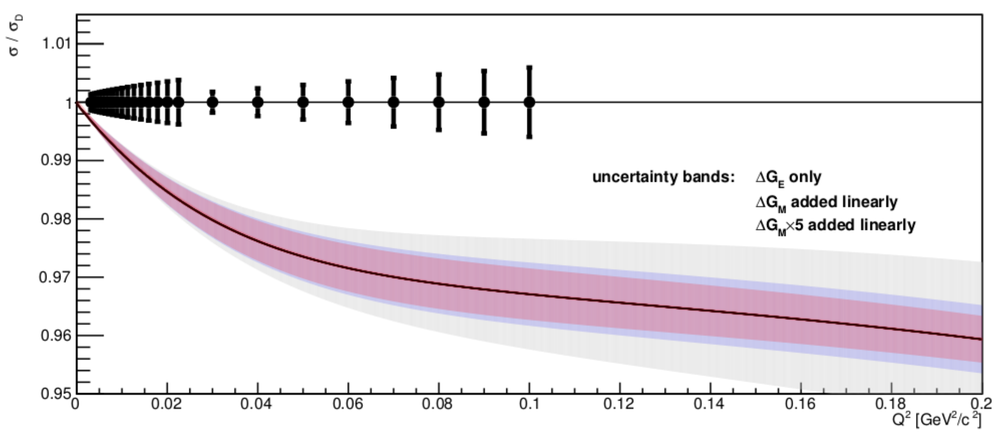
J/psi absolute rate

	283427	2015	283427 / 2015
LAS-LAST	1210±60	1270±50	0.95±0.07
OLAST	640±40	780±40	0.82±0.07
MLAST	130±20	140±20	0.93±0.21
TOTAL	1980±80	2190±70	0.90±0.05

Test in 2018 for
proton radius measurement with COMPASS

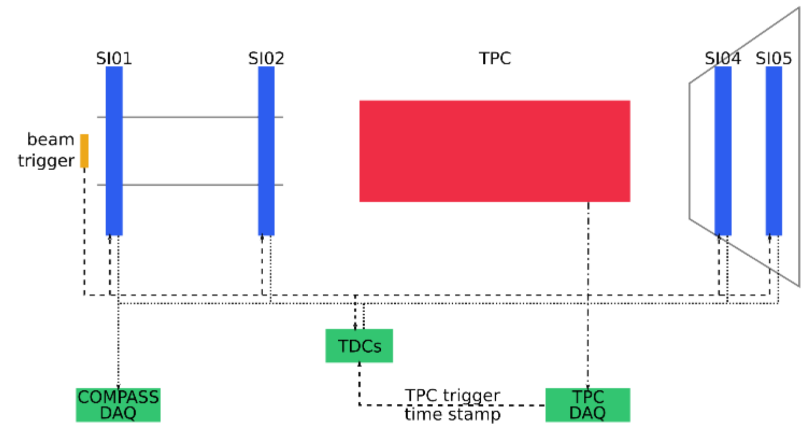
Form factor measurement in high-*E* muon-proton elastic scattering $10^{-3}\ldots10^{-2}$ GeV^2/c^2



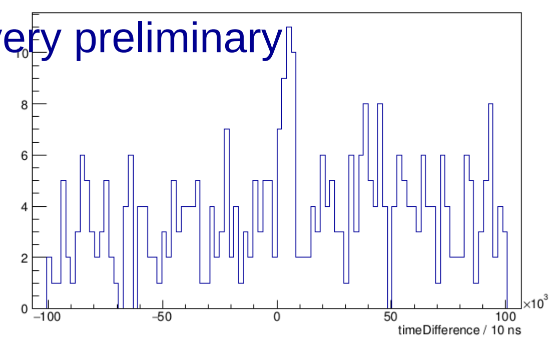


TPC for measuring proton recoils down to 0.5 MeV: Gatchina / GSI

silicon microstrip detectors for muon scattering angle measurement: COMPASS

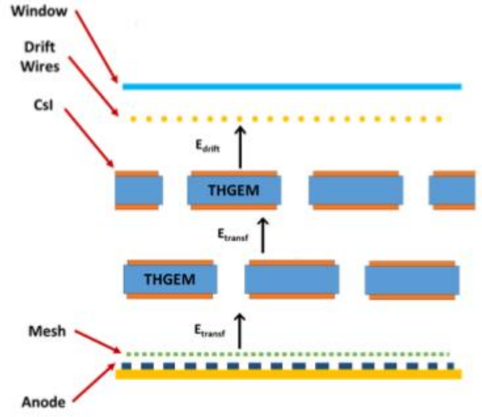


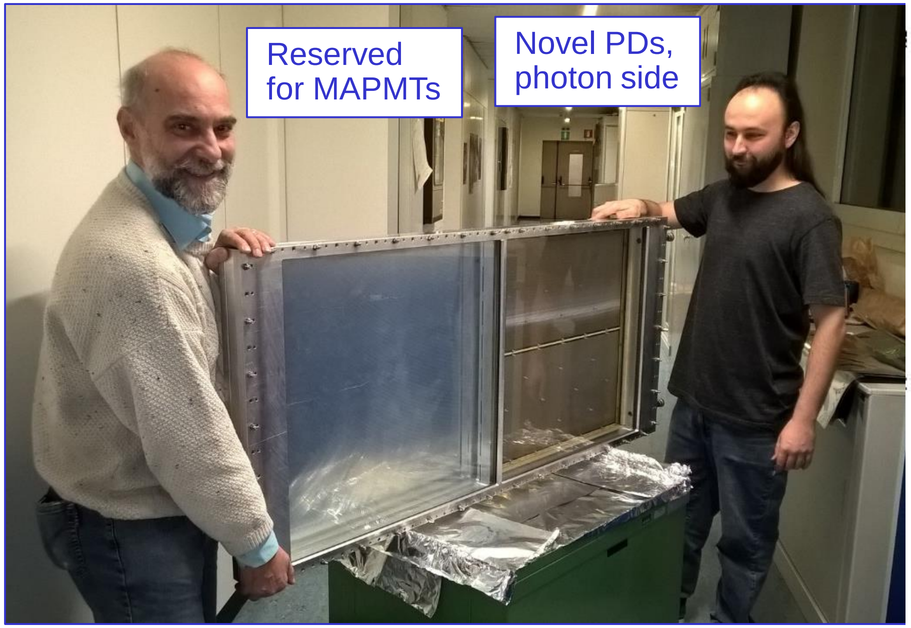
very preliminary

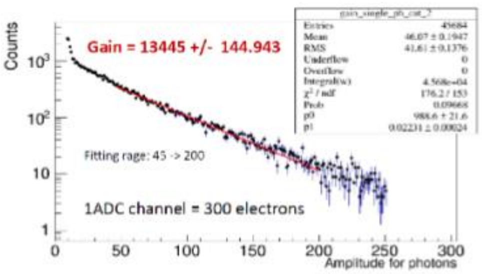


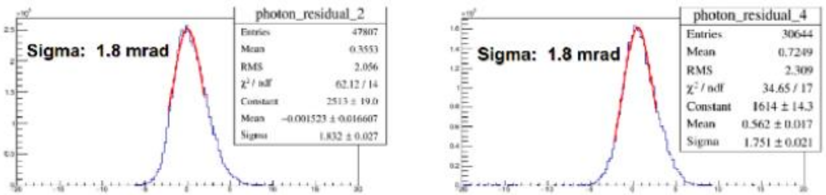
RICH detector upgrade

Upgrade with novel photon detectors: Micromegas + thick GEM hybrid
95% of active surface electrically fully stable, 80% single-photon eff.









Theta(pion) – Theta(photons) plots

Computing power and future DAQ

"Mapping proton quark structure using petabytes of COMPASS data" at

BLUE WATERS

- Blue Waters: supercomputer in Urbana-Champaign, Illinois, USA. 22,500 nodes with each 32 CPUs = 720,000 CPUs

- Allocation over 9 million node hours for COMPASS data production (real and MC)

- 1 year of COMPASS data in ~ 5 days wall time

- **Pilot MC mass production**: >12 billion events for Drell-Yan (DY, J/Psi, Psi', OC), purpose e.g multi-dimensional acceptance correction

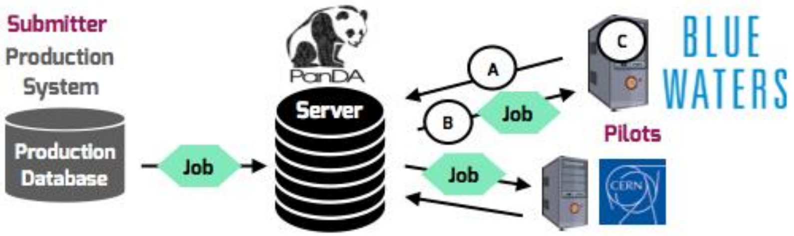
- **2-dimensional efficiency maps** of all of the 200 COMPASS tracking layers

Developments of future data acquisition systems

- COMPASS has pioneered many new developments regarding fast (dead-time free) readout schemes, e.g. APV

- recent upgrade: transition from DAQ PC farm to FPGA-based acquisition

- future developments: towards triggerless frontend and readout electronics (e.g. for proton radius)



M2 Fixed Target Experiment Beyond 2020

Writing of a new LoI for a Meson-Baryon experiment at SPS M2 line is ongoing and kept open for new people/ideas. We intend to circulate this LoI within the coming weeks.

Mini-Workshop
half-day on

*** **June 20th** ***
2pm

CERN bdg. **774**
Vidyo available

for discussing the physics covered by the LoI

save the date!

Summary table for PBC QCD conveners

3 Summary table

The main features and hardware upgrades for each Long Term Program are summarized in Tab. 1.

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 meas.	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 DM	$\overline{p}$ production cross-section	20-150	$5 \cdot 10^5$	25	p	LH 2 LHe	2022 1 month	LH2 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	Kaon polarizability	~100	$5 \cdot 10^6$	> 10	K^-	Ni	n/e 2026 1 year	
Prompt Photons	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	High Precision Strange Meson Spectrum	50-100	$5 \cdot 10^6$	25	K^-	LH2	2026 1 year	recoil TOF, forward PID

Table 1: Requirements for the 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.

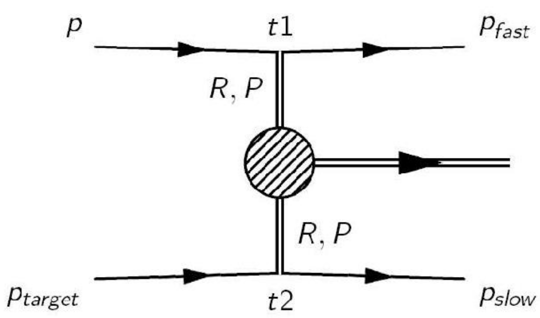
Summary

- COMPASS 2018 polarised Drell-Yan run – commissioning fast and efficient, we are taking physics data since May 17th
- Light-quark hadron spectroscopy – “legacy paper” on resonance parameters accepted by PRD, further analysis ongoing
- Good progress on the SIDIS data analysis: longitudinal, transverse/TMD and multiplicities (FF)
- Good progress on DVCS and HEMP analysis for 2012 and 2016/17 data
- Plans beyond 2020: transverse deuteron run in 2021, LoI for future collaboration

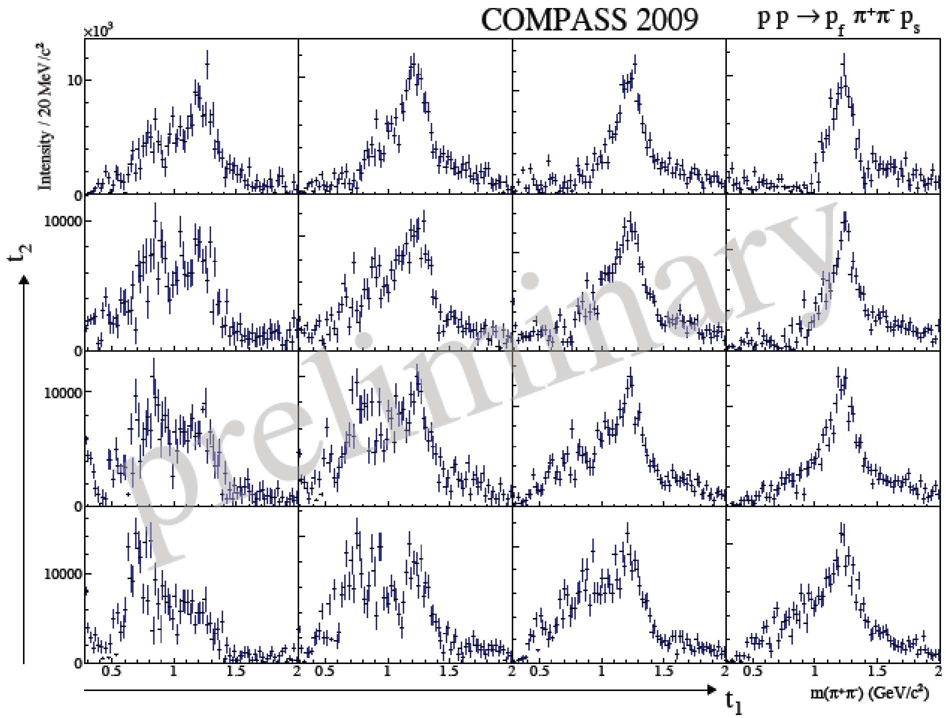
Thank you!

SPARES

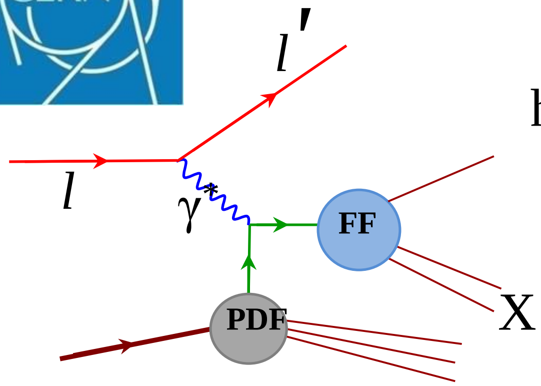
Central production II



Central production, 2008 and 2009 data.
t_1 t_2 bins, D-wave.
Interestingly, the $f_2(1270)$ signal in the D wave shows a very similar behaviour, which puts strong doubts on the common belief that the $f_2(1270)$ is produced copiously in double-Pomeron processes.

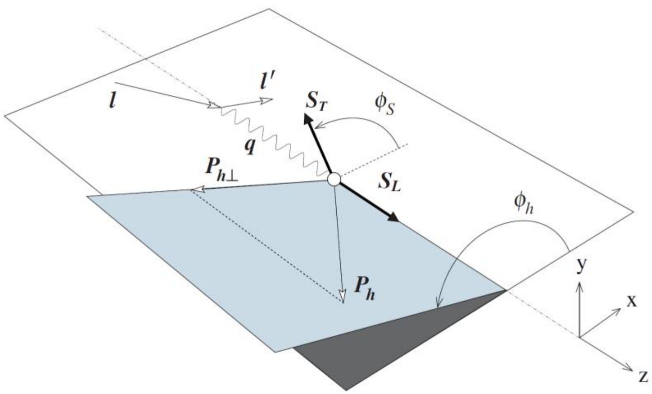


SIDIS transverse&longitudinal I



We continue to scrutinize polarised SIDIS data by studying various target spin-dependent azimuthal asymmetries.
General expression for SIDIS cross-section in terms of asym.:

$$
\begin{aligned}
\frac{d\sigma}{dx\,dy\,dz\,d(p_T^h)^2\,d\phi_h\,d\psi} &= 2\left[\frac{\alpha}{xyQ^2}\frac{y^2}{2(1-\varepsilon)}\left(1+\frac{\gamma^2}{2x}\right)\right]\left(F_{UU,T}+\varepsilon F_{UU,L}\right)\\
&\times\Big\{1+\sqrt{2\varepsilon(1+\varepsilon)}A_{UU}^{\cos\phi_h}\cos\phi_h+\varepsilon A_{UU}^{\cos(2\phi_h)}\cos(2\phi_h)+\lambda\sqrt{2\varepsilon(1-\varepsilon)}A_{LU}^{\sin\phi_h}\sin\phi_h\\
&+S_L\left[\sqrt{2\varepsilon(1+\varepsilon)}A_{UL}^{\sin\phi_h}\sin\phi_h+\varepsilon A_{UL}^{\sin(2\phi_h)}\sin(2\phi_h)\right]\\
&+S_L\lambda\left[\sqrt{1-\varepsilon^2}A_{LL}+\sqrt{2\varepsilon(1-\varepsilon)}A_{LL}^{\cos\phi_h}\cos\phi_h\right]\\
&+S_T\left[A_{UT}^{\sin(\phi_h-\phi_S)}\sin(\phi_h-\phi_S)+\varepsilon A_{UT}^{\sin(\phi_h+\phi_S)}\sin(\phi_h+\phi_S)+\varepsilon A_{UT}^{\sin(3\phi_h-\phi_S)}\sin(3\phi_h-\phi_S)\right.\\
&\qquad\left.+\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin\phi_S}\sin\phi_S+\sqrt{2\varepsilon(1+\varepsilon)}A_{UT}^{\sin(2\phi_h-\phi_S)}\sin(2\phi_h-\phi_S)\right]\\
&+S_T\lambda\left[\sqrt{\left(1-\varepsilon^2\right)}A_{LT}^{\cos(\phi_h-\phi_S)}\cos(\phi_h-\phi_S)\right.\\
&\qquad\left.+\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos\phi_S}\cos\phi_S+\sqrt{2\varepsilon(1-\varepsilon)}A_{LT}^{\cos(2\phi_h-\phi_S)}\cos(2\phi_h-\phi_S)\right]\Big\},
\end{aligned}
$$



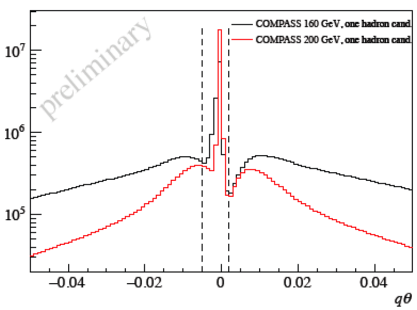
LO LSA/TSA	twist-2: PDF ⊗ FF
$A_{UL}^{\sin(2\phi_h)}$	$h_{1L}^{\perp q}\otimes H_{1q}^{\perp h}$
A_{LL}	$g_{1L}^{q}\otimes D_{1q}^{h}$
$A_{UT}^{\sin(\phi_h-\phi_S)}$	$f_{1T}^{\perp q}\otimes D_{1q}^{h}$
$A_{UT}^{\sin(\phi_h+\phi_S-\pi)}$	$h_{1}^{q}\otimes H_{1q}^{\perp h}$
$A_{UT}^{\sin(3\phi_h-\phi_S)}$	$h_{1T}^{\perp q}\otimes H_{1q}^{\perp h}$
$A_{LT}^{\cos(\phi_h-\phi_S)}$	$g_{1T}^{q}\otimes D_{1q}^{h}$

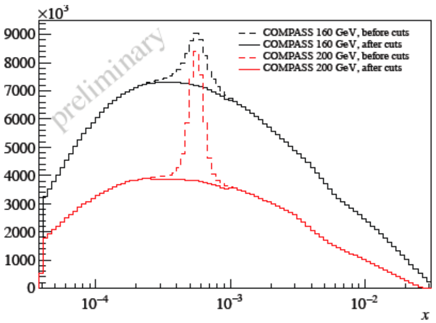
subleading LSA/TSA	higher-twist PDF ⊗ FF	WWA twist-2: PDF ⊗ FF
$A_{UL}^{\sin(\phi_h)}$	$xh_L^q\otimes H_{1q}^{\perp h}$, $xf_L^{\perp q}\otimes D_{1q}^h$	$h_{1L}^{\perp q}\otimes H_{1q}^{\perp h}$
$A_{LL}^{\cos(\phi_h)}$	$xe_L^q\otimes H_{1q}^{\perp h}$, $xg_L^{\perp q}\otimes D_{1q}^h$	$g_{1L}^q\otimes D_{1q}^h$
$A_{UT}^{\sin(\phi_S)}$	$xf_T^q\otimes D_{1q}^h$, $xh_T^q\otimes H_{1q}^{\perp h}$, $xh_T^{\perp q}\otimes H_{1q}^{\perp h}$	$f_{1T}^{\perp q}\otimes D_{1q}^h$, $h_1^q\otimes H_{1q}^{\perp h}$
$A_{UT}^{\sin(2\phi_h-\phi_S)}$	$xf_T^{\perp q}\otimes D_{1q}^h$, $xh_T^q\otimes H_{1q}^{\perp h}$, $xh_T^{\perp q}\otimes H_{1q}^{\perp h}$	$f_{1T}^{\perp q}\otimes D_{1q}^h$, $h_1^q\otimes H_{1q}^{\perp h}$
$A_{LT}^{\cos(\phi_S)}$	$xg_T^q\otimes D_{1q}^h$, $xe_T^q\otimes H_{1q}^{\perp h}$, $xe_T^{\perp q}\otimes H_{1q}^{\perp h}$	$g_{1T}^q\otimes D_{1q}^h$
$A_{LT}^{\cos(2\phi_h-\phi_S)}$	$xg_T^{\perp q}\otimes D_{1q}^h$, $xe_T^q\otimes H_{1q}^{\perp h}$, $xe_T^{\perp q}\otimes H_{1q}^{\perp h}$	$g_{1T}^q\otimes D_{1q}^h$

SIDIS longitudinal II

Proton 2007 and 2011 $Q^2 < 1$

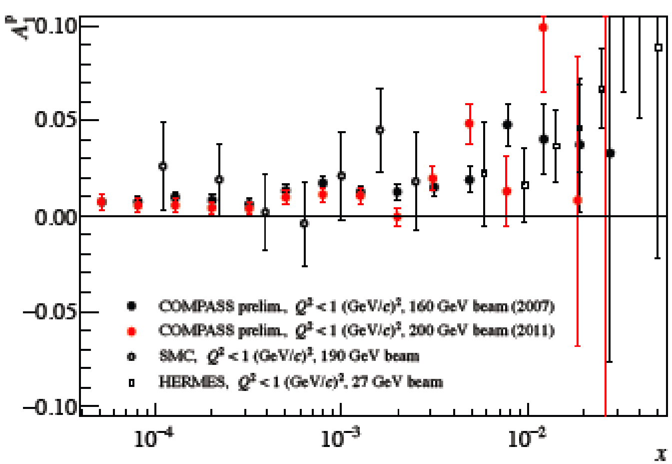
The main challenge in the low-Q^2 analysis is the suppression of events due to muon scattering off target electrons. These events are removed by a cut on the product of the angle between the virtual photon and the electron candidate and the particle charge $q\vartheta$.

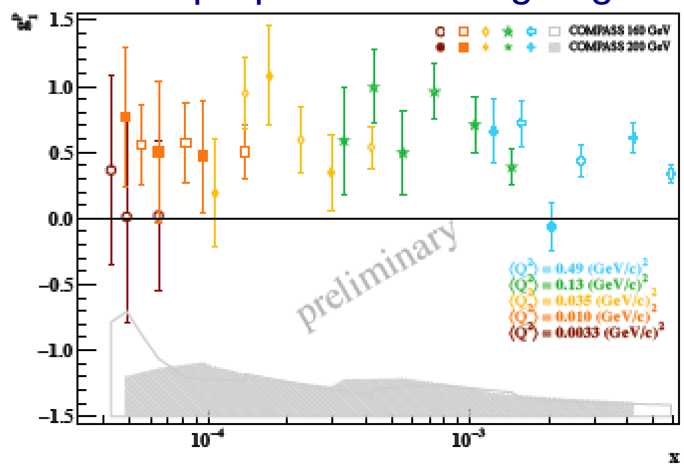




The results for A_1^p for both data sets are compared to previous measurements. The increase in precision is evident. The COMPASS data show a small, nearly constant asymmetry of about 1% at small x. The resulting values for g_1^p are shown in together with the systematic error band. For comparison with model predictions various binnings, e.g. x, Q^2 and ν, x.

The preparation is ongoing.





SIDIS transverse

New approach continued: weighted asymmetries

Asymmetries obtained by weighting the spin-dependent part of the cross-section with powers of $p^h{}_T$.

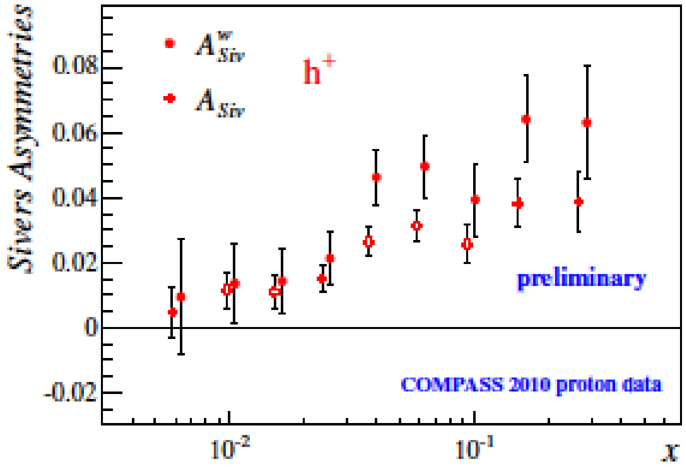
Main advantage - convolution integrals becomes products ➔ no parametrization of the unknown transverse momentum dependence of PDFs and FFs is needed.

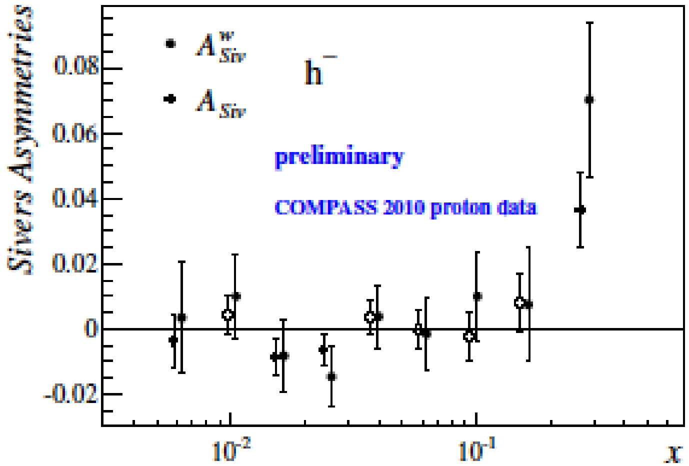
$$A_{Siv}^{(p_T^h/zM)}(x,z) = 2\frac{\sum_q e_q^2 f_{1T}^{\perp(1)\,q}(x)\cdot D_1^q(z)}{\sum_q e_q^2 f_1^q(x)\cdot D_1^q(z)},$$

<u>Important</u>: large statistics, good acceptance.

Allows to extract first moment of Sivers

$$f_{1T}^{\perp(1)}(x,Q^2) = \int d^2k_T \frac{k_T^2}{2M^2} f_{1T}^{\perp}(x,k_T,Q^2).$$



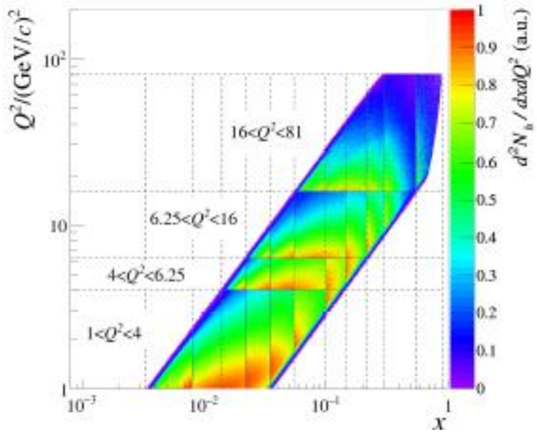


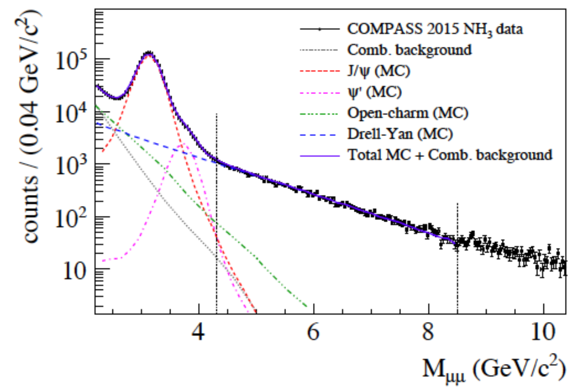
This is a first data on $p^n{}_T$ weighted Sivers asymmetry

SIDIS transverse

Sivers and TSA in the Drell-Yan Q^2 bins

Sivers TMD PDF has a very particular feature - it contributes with opposite sign to SIDIS and DY. It is considered to be an essential prediction of Quantum Chromodynamics (QCD) going to be tested by COMPASS. If Sivers function comparison SIDIS←→ DY is done at the same Q^2 we drop the uncertainties from the unknown QCD evolution of the Sivers TMD.





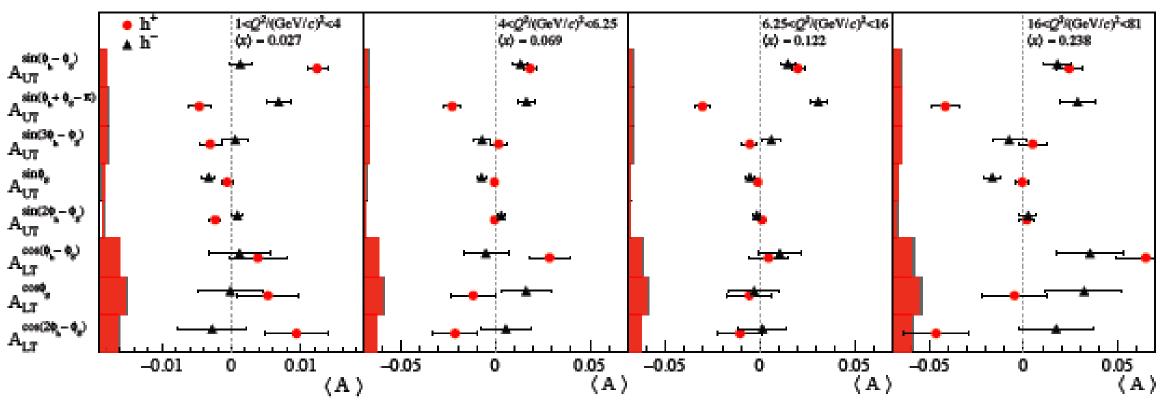
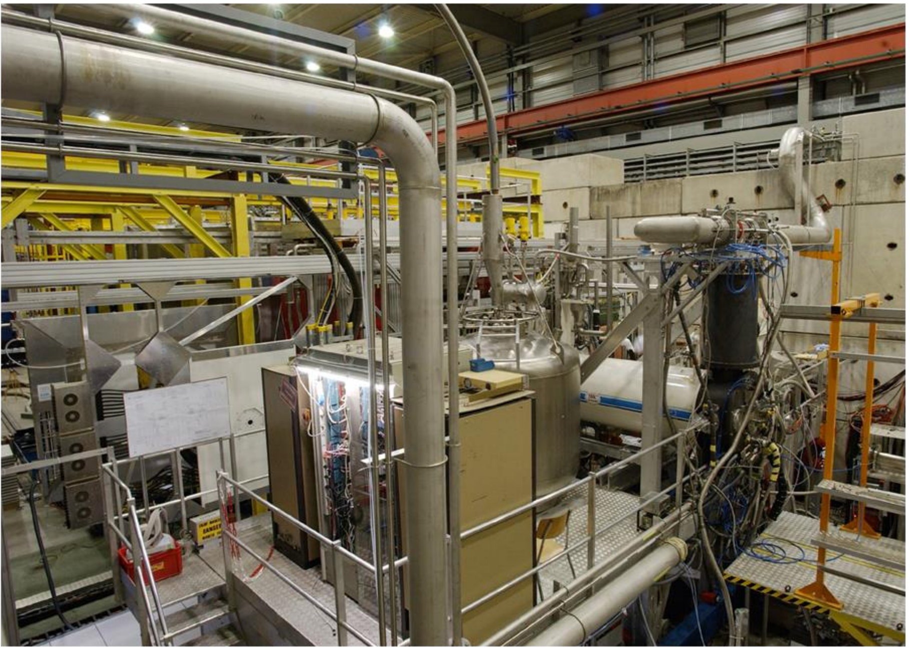


Fig. 2: Mean TSAs in the four DY Q^2-ranges. Systematic uncertainties are shown as error bands next to the vertical axis. For each Q^2-range also the average x-values are given.

SIDIS longitudinal



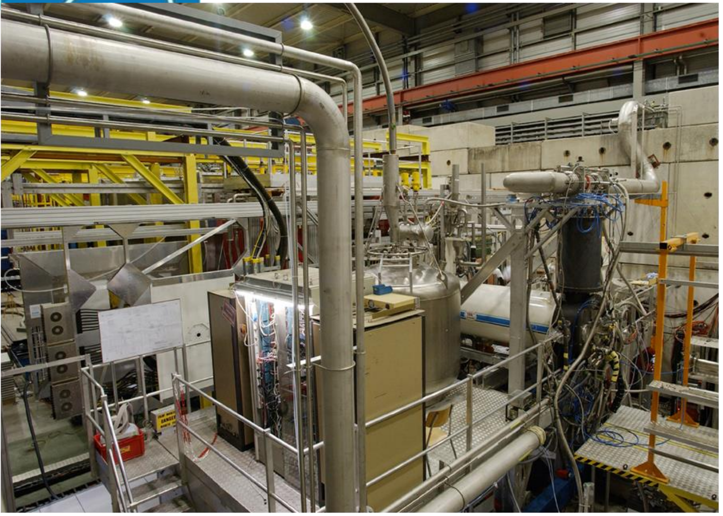
Deuteron data:
Published:
2002 and 2004 $Q^2>1$

This report – Deuteron 2006 $Q^2>1$

Proton data:
Published:
2007, 2011 $Q^2 > 1$

This report: Proton 2007, 2011 $Q^2 < 1$

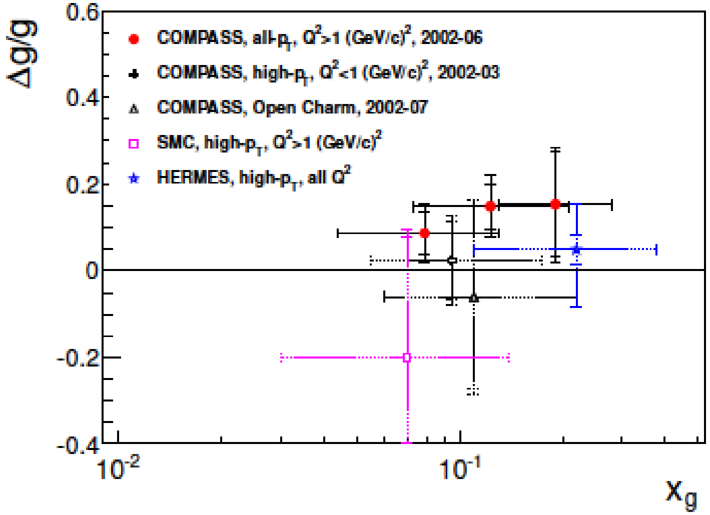
(SI)DIS longitudinal I – Final results

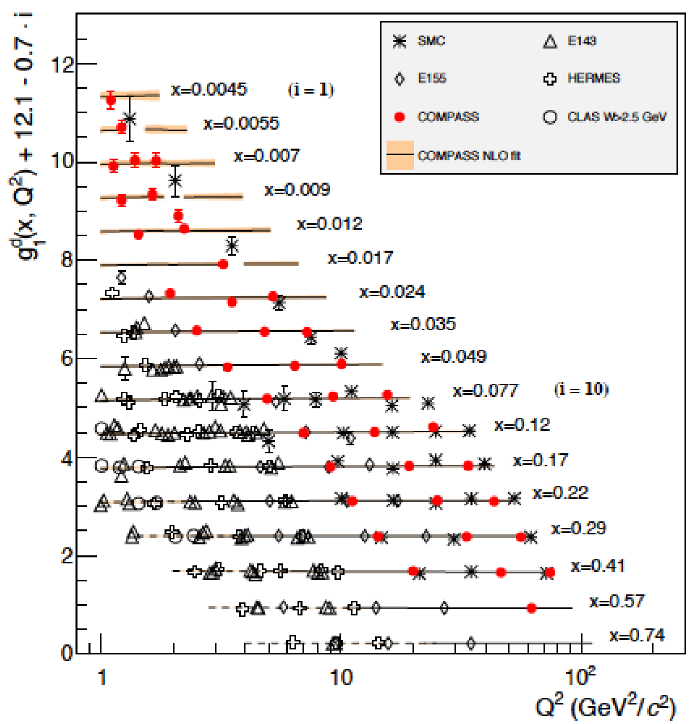


Deuteron g_1^d $Q^2>1$

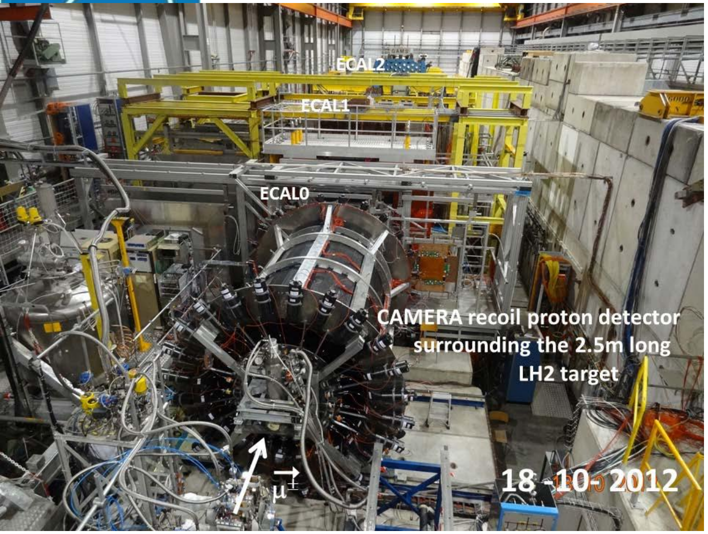
Published the final COMPASS result for double spin asymmetry A_1^d and longitudinal spin structure function g_1^d (deuteron data set 2002-2004, 2006) PLB 769 (2017) 034. Together with the results on the proton spin structure function g_1^p , these results constitute the COMPASS legacy on the measurements of the g_1 structure function.

All Deuteron data $\Delta g/g$ final result EPJC 77 (2017) 209





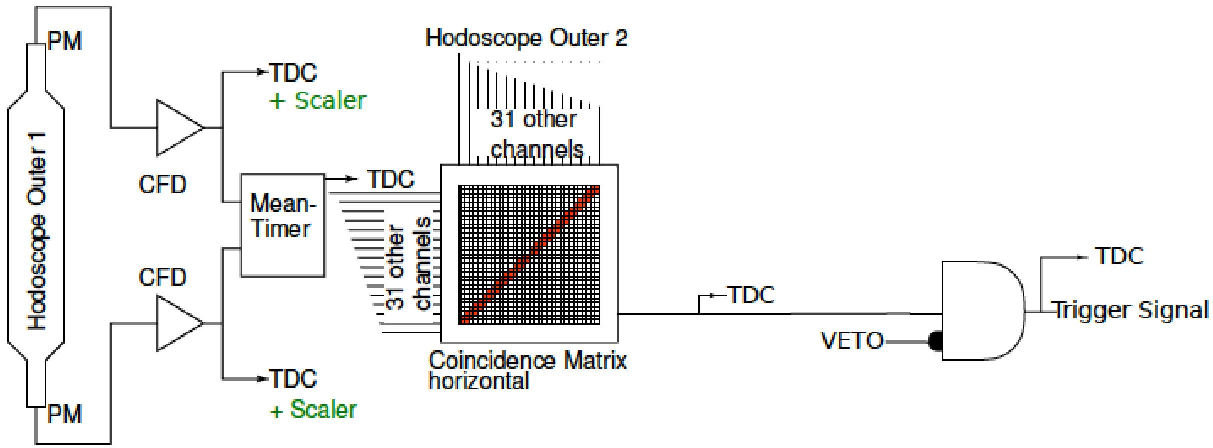
Change over for Polarised Drell-Yan run



Group	function		comment	Contacted?
Various TE-CRG-ML	Helium, piping, magnets		Reserve people, Check availability	yes
EN-EL	Electricity, cabling		400V, 48V, AUL	yes
TE-EPC-LPC	Power supplies		Ready Jan. 2018	yes
DT-DI	Programming, connection			yes
EN-HE	Platform, rotation, shielding			yes
TE-CRG-OD	Helium consumption Cold box Dewar LN_2		Check for larger Dewar Check piquet service	yes
EN-EA	CEDAR/magnet support			Asking soon

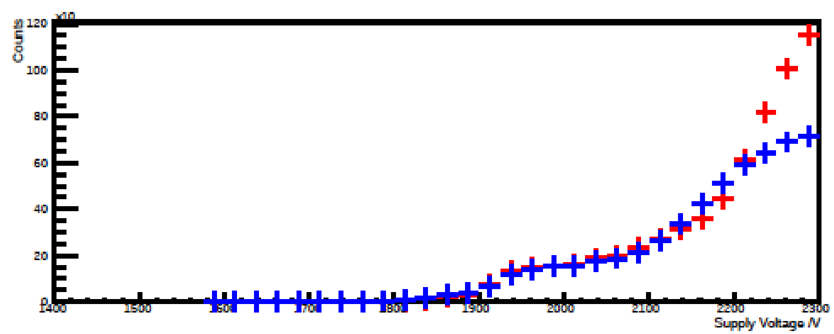
Better trigger performance control

Additional Monitoring Features



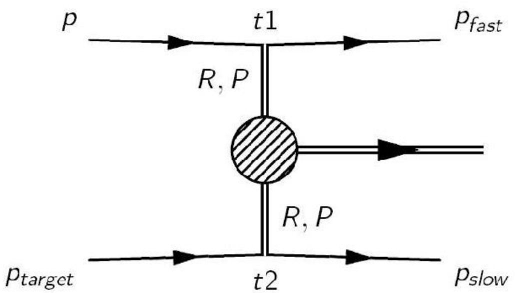
Adding signal splitter and scaler direct after the CFDs:

- Real-time monitoring of un-triggered rates of PMTs
- Determination of workingpoint under final condition for all PMTs

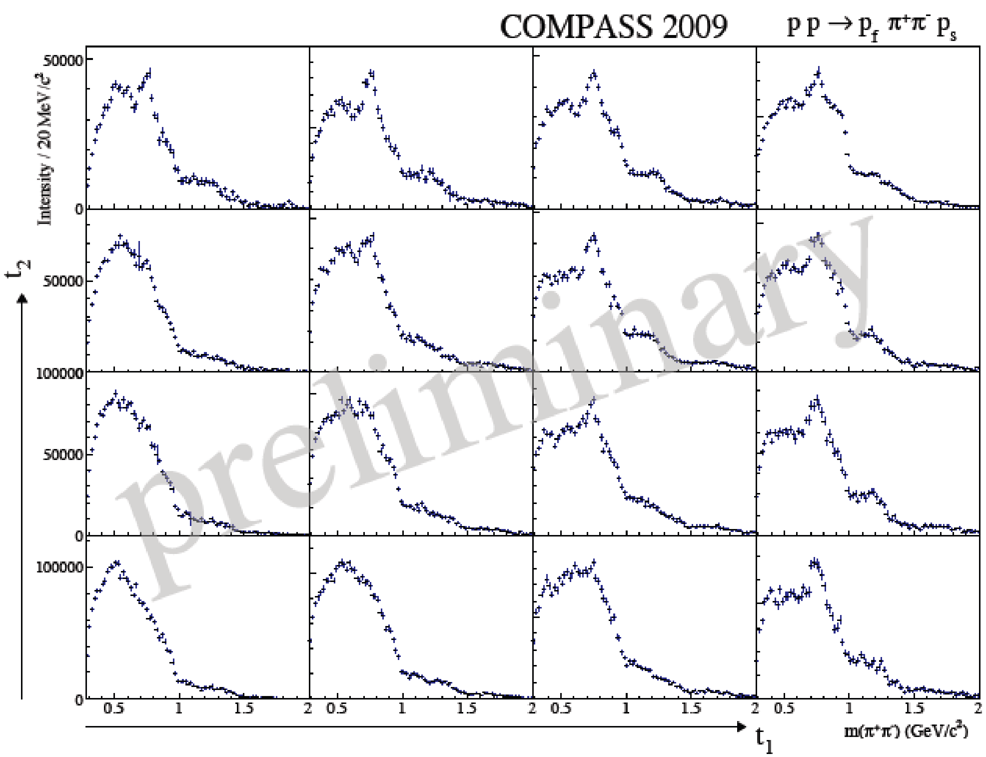


Central production I

Central production, proton beam in 2008 and 2009.



Analysis is in progress:
- two mesons in the final state ($\pi^+\pi^-$, $\pi^0\pi^0$ and $K^+ K^-$)
- at COMPASS kinematics P-R, R-R and diffraction processes
- *S, P* and *D* waves (spin projection M ≤ 1) contribute significantly.



S wave exhibit some contamination by ρ(770) meson – to clarify PWA was performed in t_1 t_2 bins.

Low t_1 and t_2 - ρ (770) signal has practically vanished. These bins are dominated by a double-Pomeron exchange mechanism where ρ production is forbidden (C-parity conservation)

More work is needed to develop a method that correctly takes into account the ρ(770) contamination in the *S*-wave.

Mapping Proton Quark Structure using Petabytes of COMPASS data

NSF grant#1713684

- Blue Waters: supercomputer at NCSA (National Center for Supercomputing Applications) in Urbana-Champaign, Illinois, USA. 22,500 nodes with each 32 CPUs = 720,000 CPUs

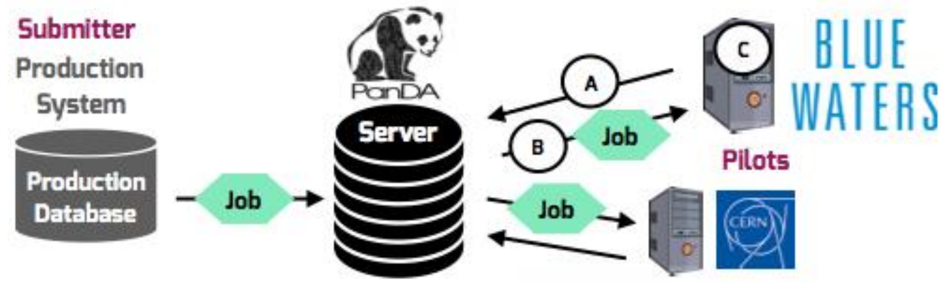
- Allocation over 9 million node hours for COMPASS data production (real and MC)

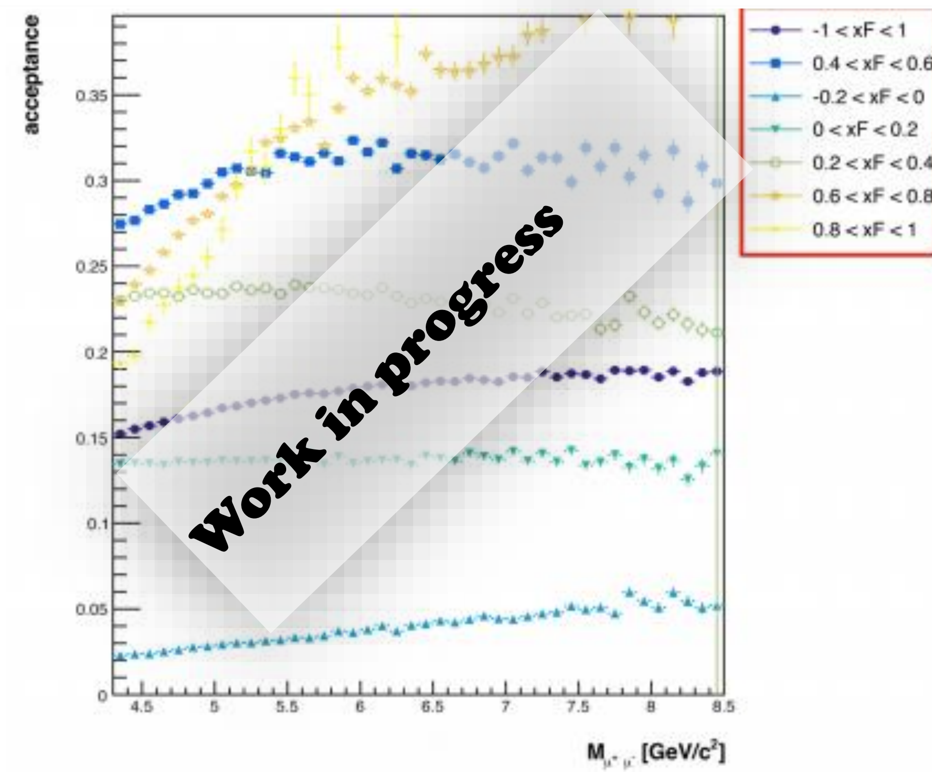
- Blue Waters will allow to process 1 year of COMPASS data taking in ~ 5 days wall time. **Pilot Real Data productions with PanDA.**

    - PanDA = Production ANd Distributed Analysis = data production and monitoring system developed for ATLAS-LHC.

- **Pilot MC mass production**: >12 billion events for Drell-Yan (DY, J/Psi, Psi', OC), purpose e.g. multi-dimensional acceptance correction

- **2-dimensional efficiency maps** of all of the ~ 200 COMPASS tracking layers.





BLUE WATERS

(SI)DIS longitudinal II

Proton 2007 and 2011 $Q^2 < 1$

Large gain in the precision (see A_1^p for both data).

Small, nearly constant asymmetry of about 1% at small x.

The resulting values for g_1^p will be published in various binnings, e.g. x, Q^2 and ν, x for comparison with theory predictions.

The paper preparation is ongoing.