COMPASS

Physics, Highlights, Future Plans

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on behalf of the COMPASS collaboration

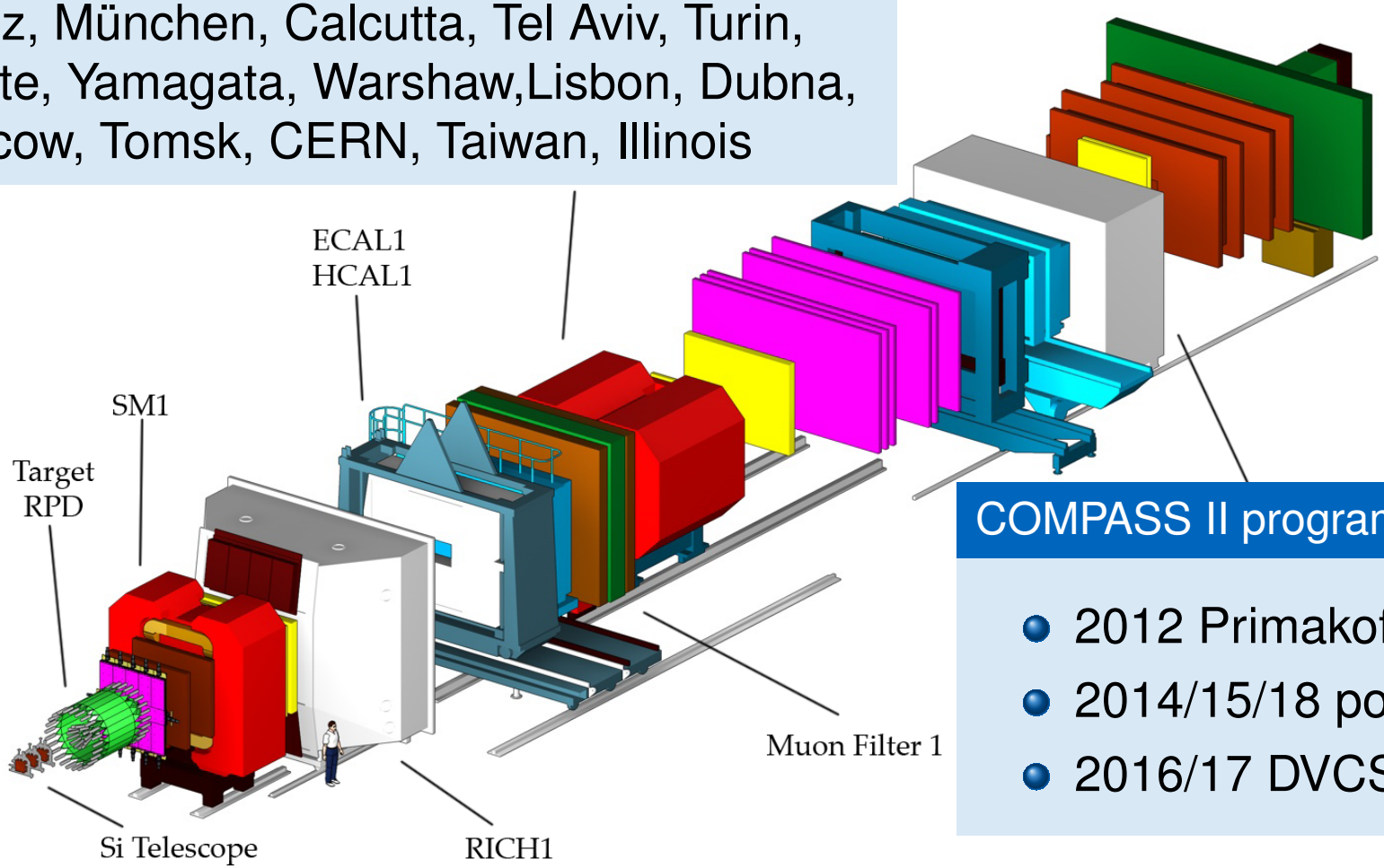
Geneva
10.3.2017

bmb+f - Förderschwerpunkt
COMPASS
Großgeräte der physikalischen Grundlagenforschung

The COMPASS Experiment

Collaboration: 249 members

22 institutes: Prague, Saclay, Bonn, Freiburg, Mainz, München, Calcutta, Tel Aviv, Turin, Trieste, Yamagata, Warshaw,Lisbon, Dubna, Moscow, Tomsk, CERN, Taiwan, Illinois



COMPASS II program

- 2012 Primakoff $\{\pi/K\}\gamma$
- 2014/15/18 pol. DY
- 2016/17 DVCS / SIDIS

The Physics Case: Exploring QCD

with a multi-purpose setup

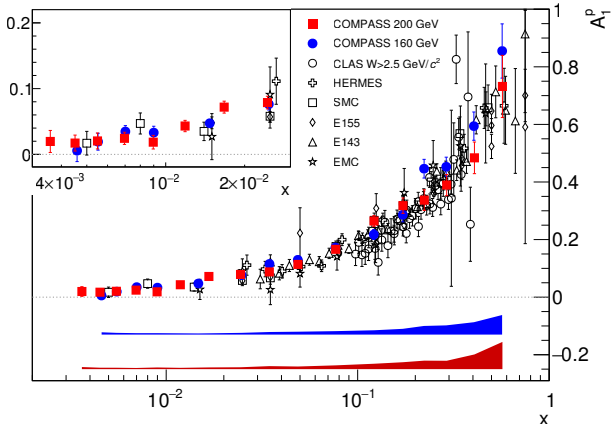
- Deep-inelastic muon scattering
  with longitudinal and transverse target polarisation
- High-energy hadron scattering
  at low and intermediate excitation energies
- Primakoff reactions: $\pi^{\pm}$ polarisability, chiral dynamics
- (First) Polarised Drell-Yan
  with pion beam
- Exclusive muon-induced processes
  - deeply-virtual Compton scattering
  - hard exclusive meson production

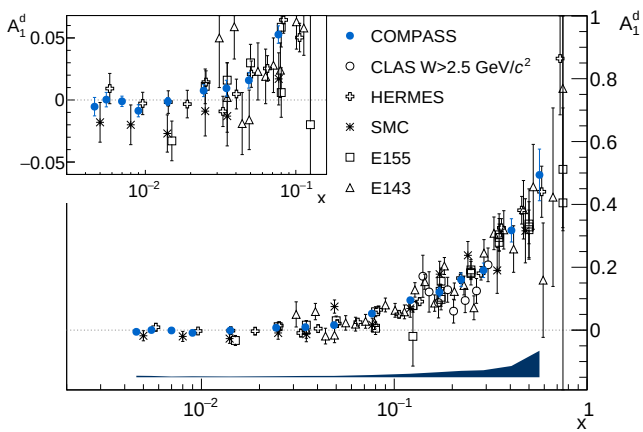
Results on g_1^p and g_1^d

longitudinal spin-dependent structure functions

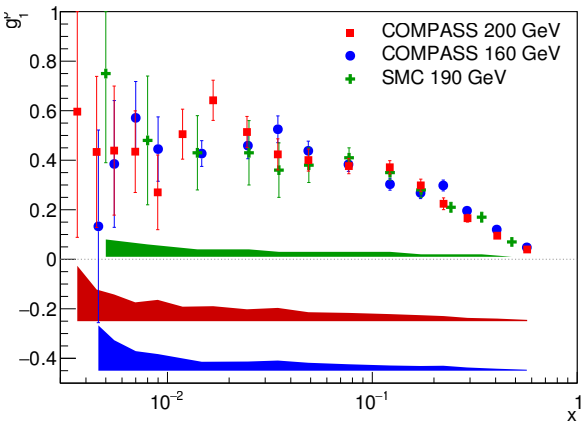
PLB 753 (2016) 18 — proton — deuteron — hep-ex/1612.00620

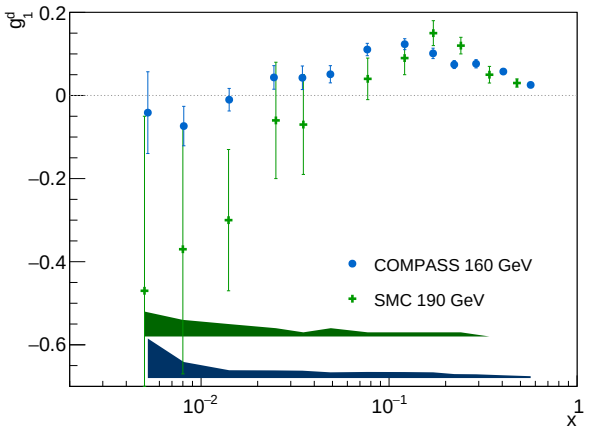
A_1





g_1

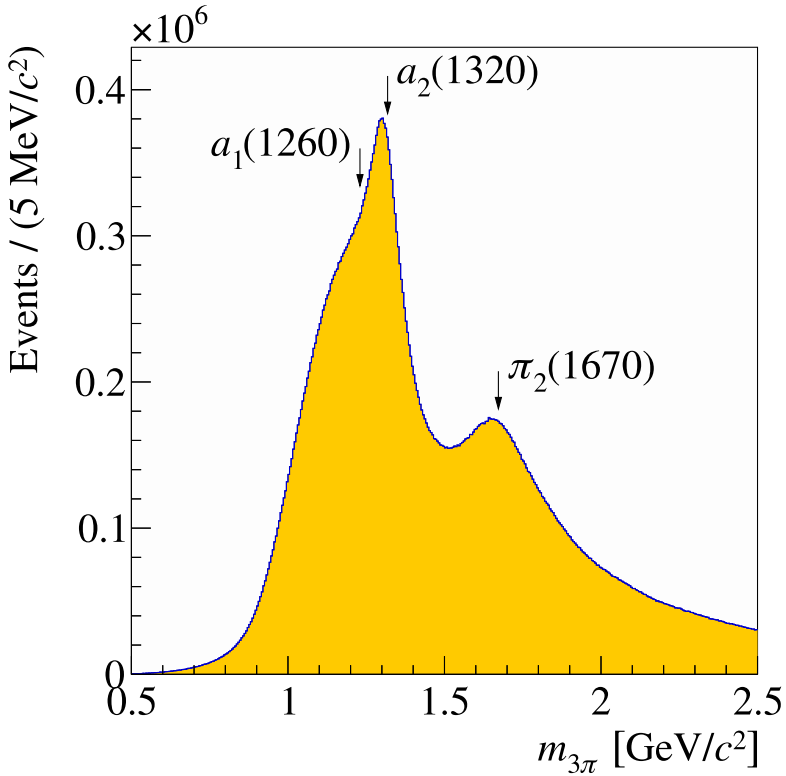




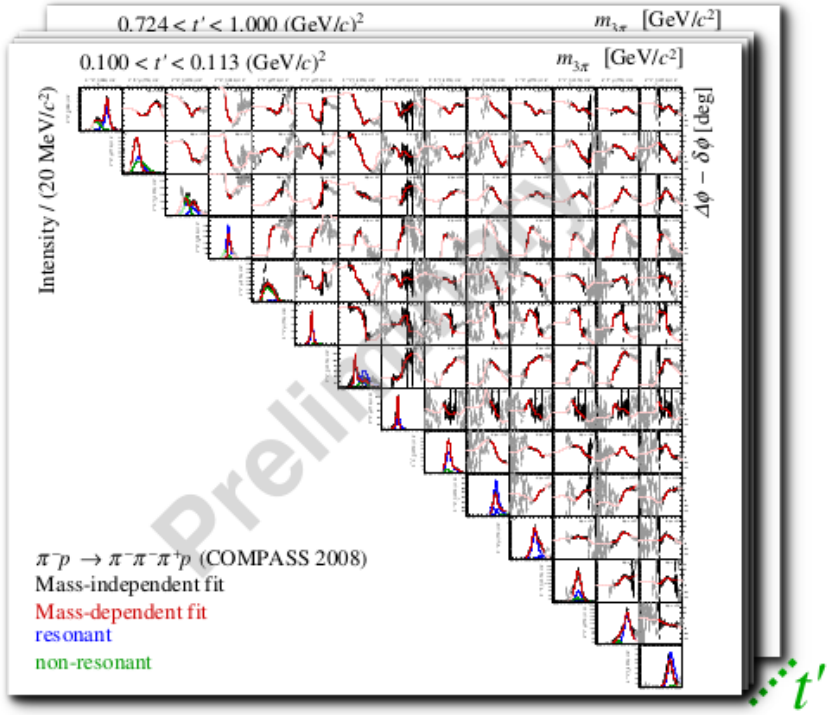
- first moment Γ_1: verification of Bjorken sum rule (94% in cov. range)
- NLO QCD fit $\rightarrow$ polarised parton distributions, $0.26 < \Delta\Sigma|_{Q^2=3} < 0.36$

Meson spectroscopy: 3π final state

arXiv:1509.00992

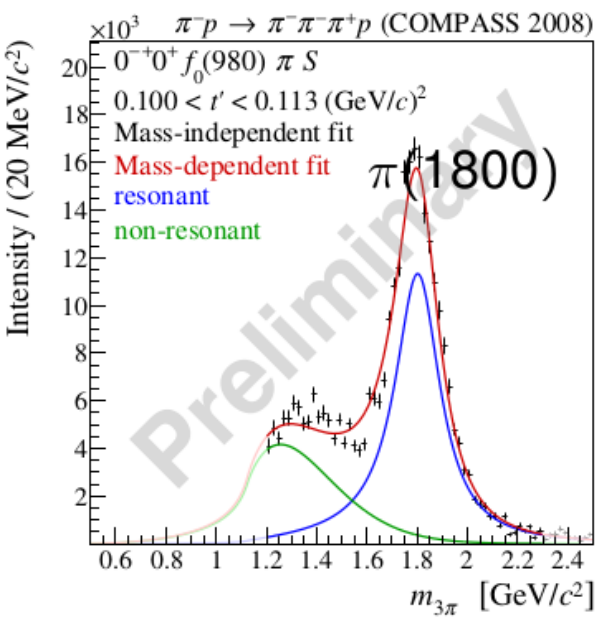


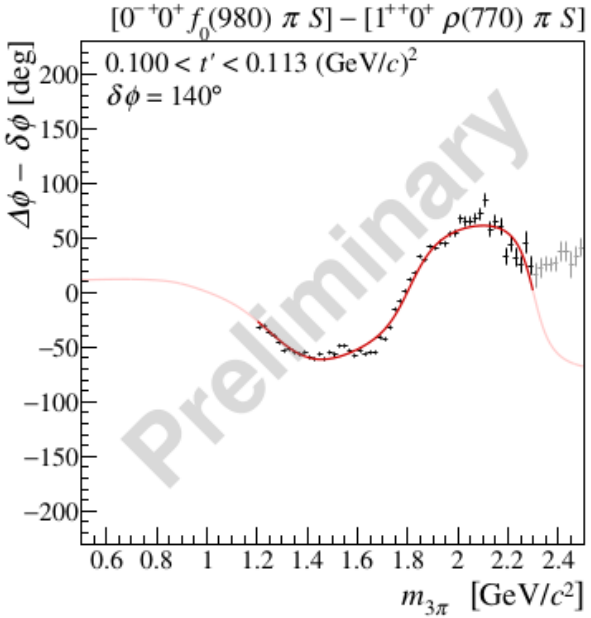
$\Rightarrow$

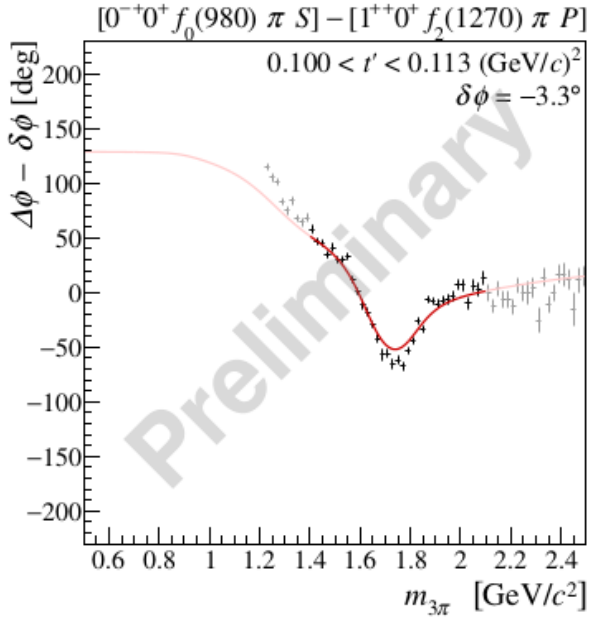


- 46 million exclusive 3π events
- partial-wave fit with 88 waves in narrow 3π-mass slices
- mass dependence fitted for 14 waves $\sim$ 75 000 data points (including interference terms)

Example: $0^{-+}0^{+}f_0(980)\pi S$ wave





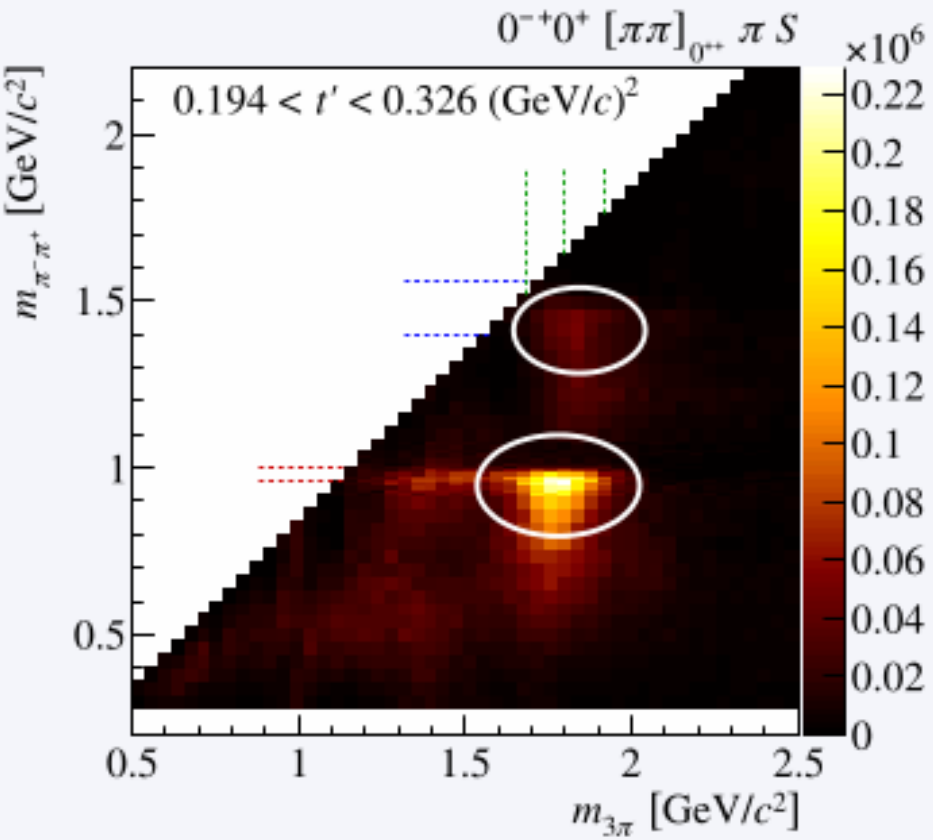


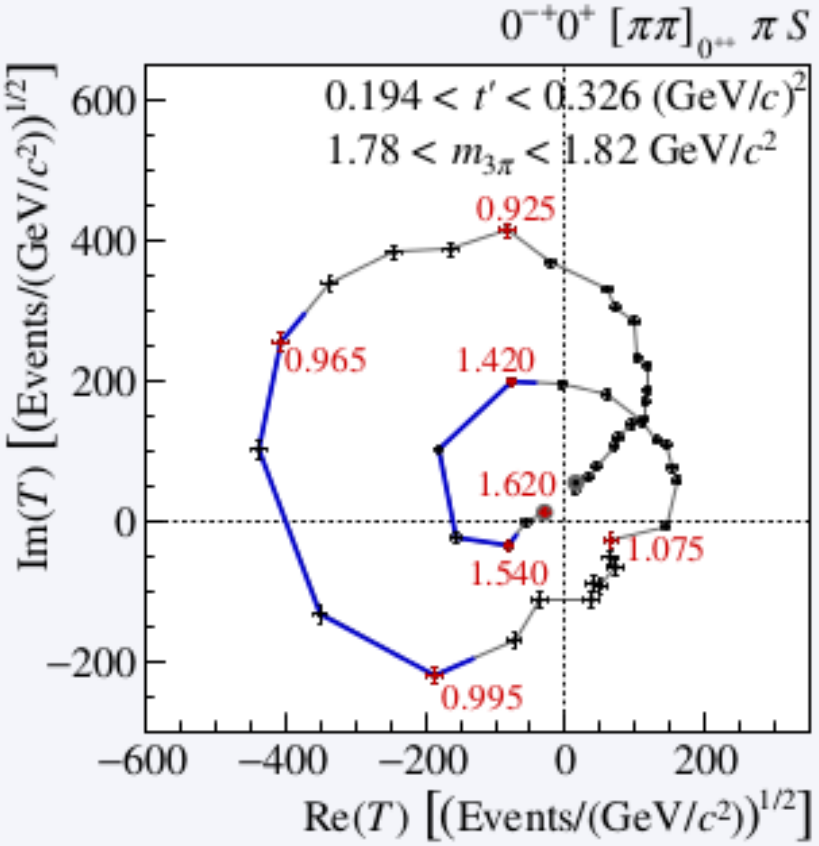
$$m_{\pi(1800)} = 1802.6^{+8}_{-3.5}\,\mathrm{MeV}/c^2\ ;\ \Gamma_{\pi(1800)} = 218^{+11}_{-6}\,\mathrm{MeV}/c^2$$

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

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

De'isobar'ing of $\pi(1800)$





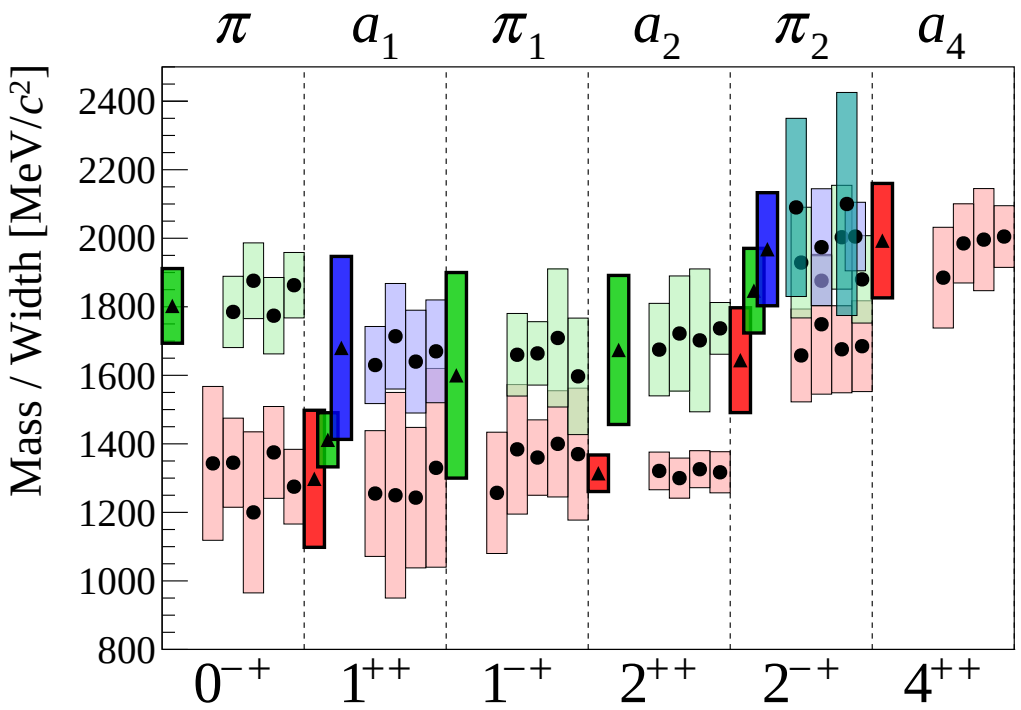
- Coupling of $\pi(1800)$ to $f_0(980)\pi$ and $f_0(1500)\pi$ decay modes

$\rightarrow$ 2π-isobar parameters can be extracted from the 3π final states *(ongoing)*

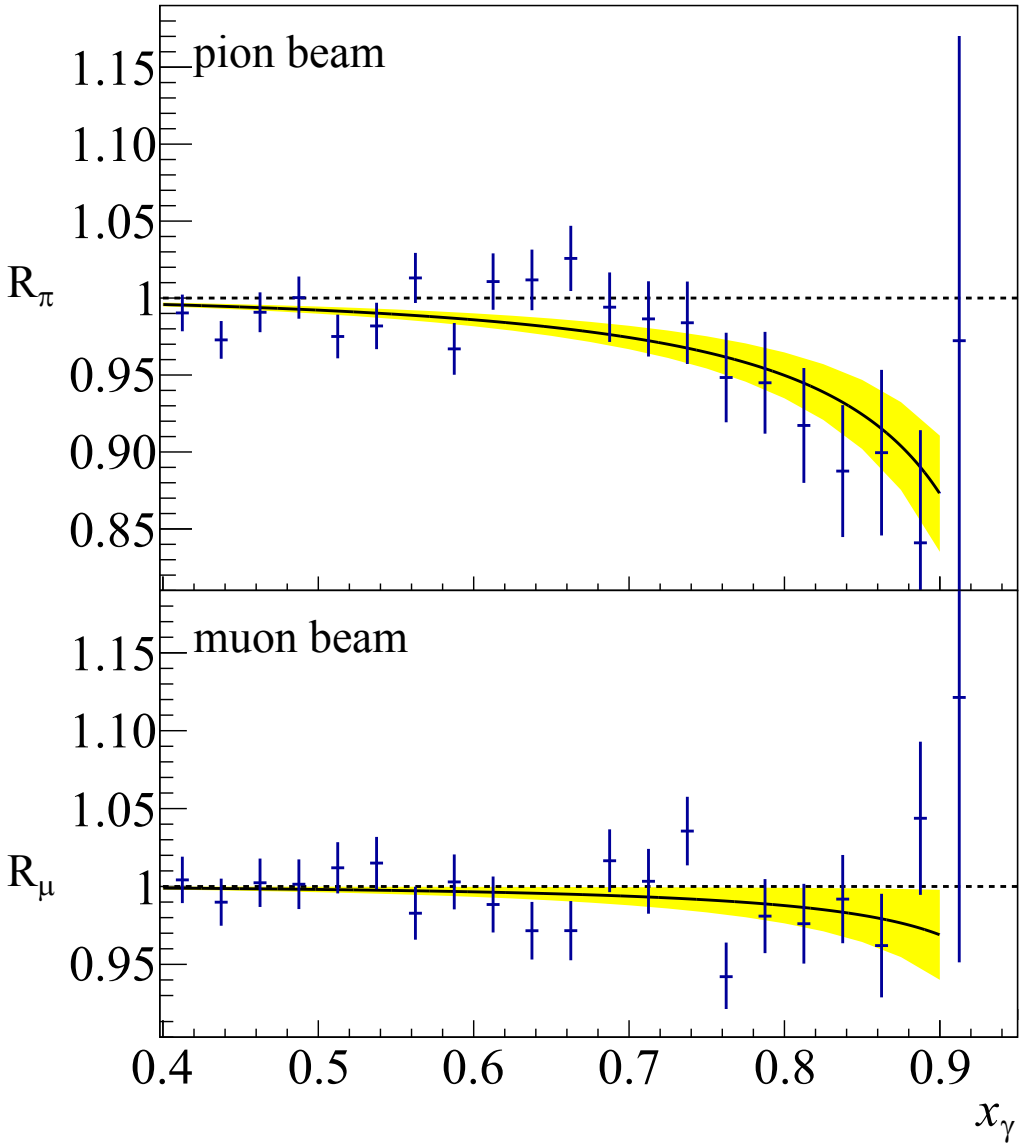
Results on 3π resonances

new: parameters of 11 resonances

- main known resonances reproduced
- all resonance parameters determined in one single fit
- new signal: $a_1(1420)$
- three π_2 states needed
- (broad) exotic 1^{-+} signal



Pion Polarisability: COMPASS 2009 data



$$\alpha_\pi = (2.0 \pm 0.6_{\text{stat}}) \times 10^{-4}\,\text{fm}^3$$

(assuming $\alpha_\pi = -\beta_\pi$)

"false polarisability" (muon data):

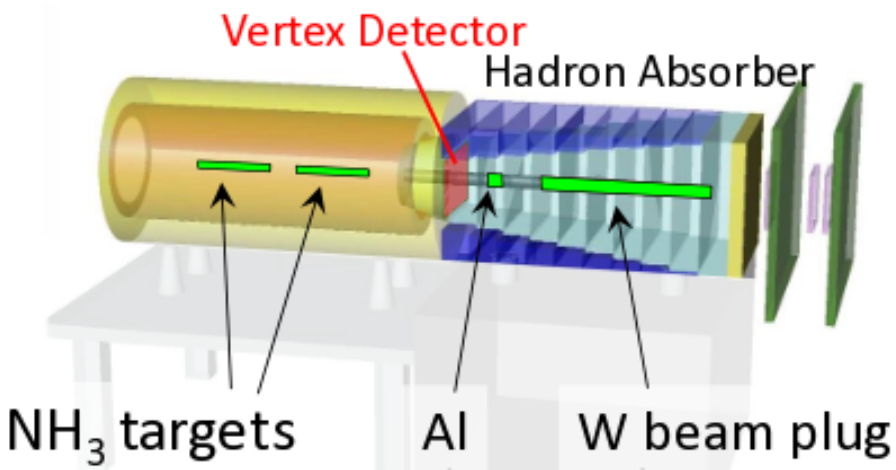
$$(0.5 \pm 0.5_{\text{stat}}) \times 10^{-4}\,\text{fm}^3$$

PRL 114, 062002 (2015)

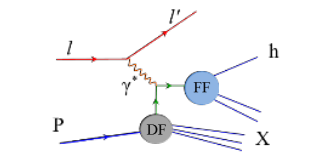
Press release 11.2.2015:
"CERN experiment brings precision to a cornerstone of particle physics"

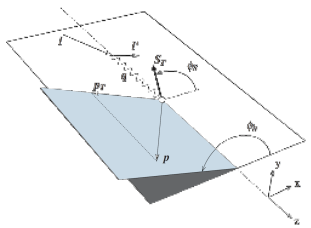
Polarised Drell-Yan 2015

Sivers asymmetry - *news about sign question expected soon*

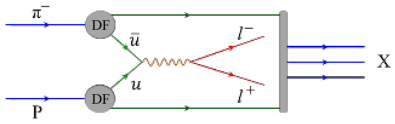


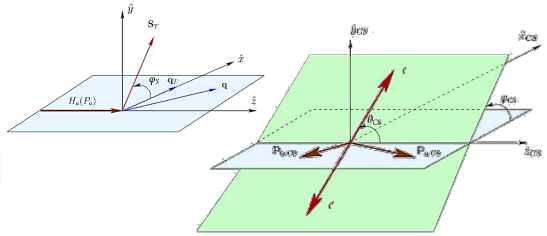
SIDIS

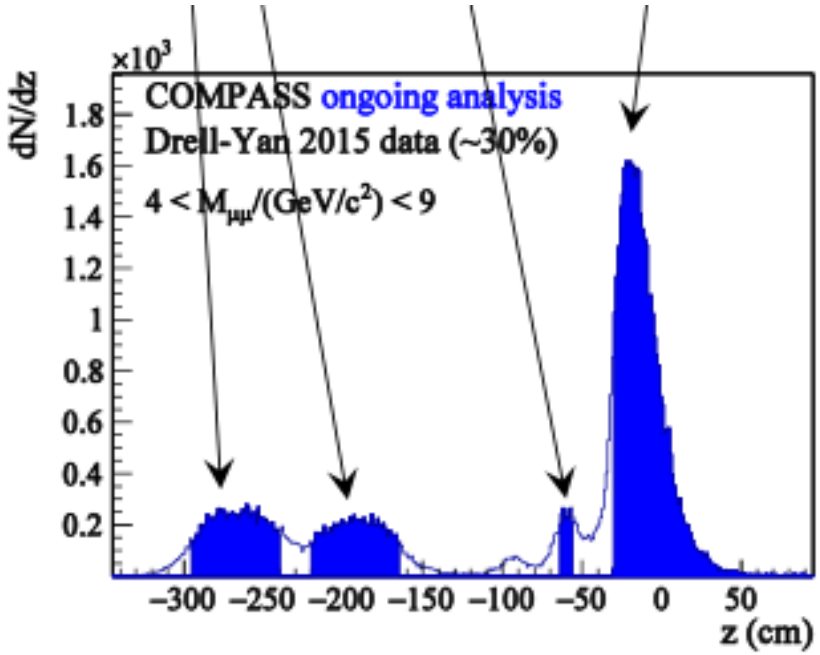


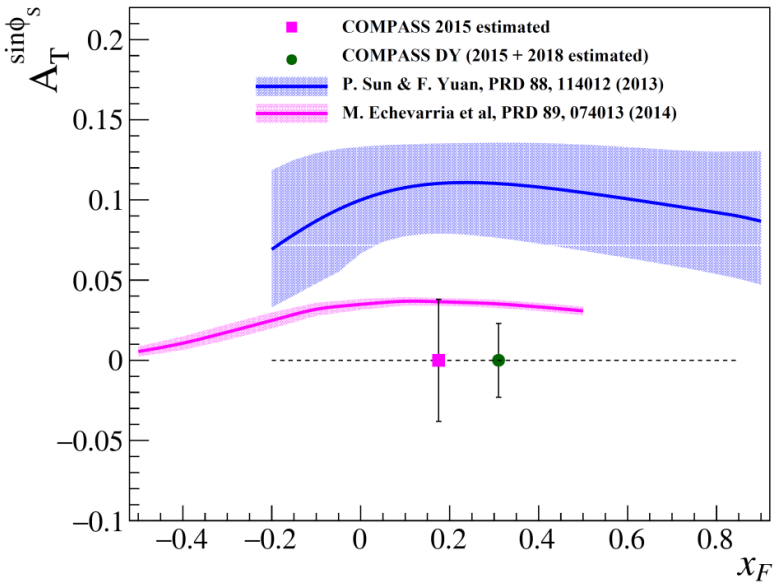


single-polarised DY



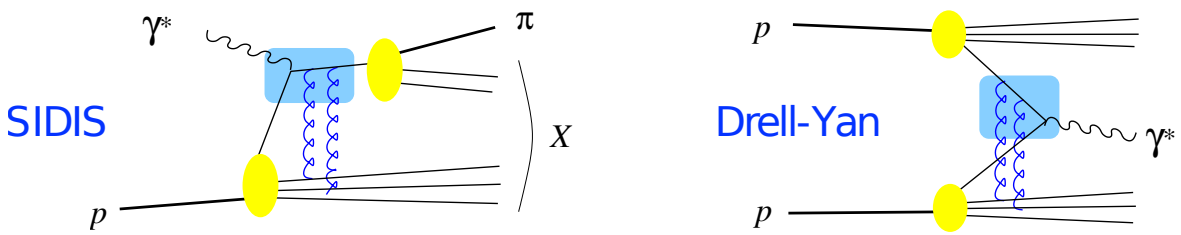






Target spin asymmetries in pDY

- transverse momentum distribution of partons is shifted in transversely polarised proton (Sivers effect)
  - ★ spin-orbit coupling, sensitive to orbital angular mom.
- effect comes from soft gluon exchange in physical process



  - ★ definite change of distribution between SIDIS and DY:

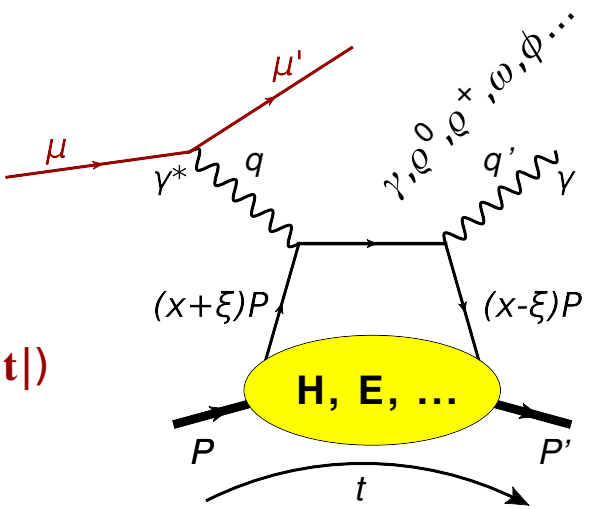
$$f_{\text{Sivers, SIDIS}}(x,k_T) = -\, f_{\text{Sivers, DY}}(x,k_T)$$

  - ★ fundamentally tests our understanding of soft gluon effects on hadron structure
- related: Boer-Mulders shift for transv. quark pol. in unpol. p

from: M. Diehl, PBC Working Group Meeting March 2017

DVCS: Transverse Nucleon Imaging

$$\vec{\mu}^{\pm} p \rightarrow \mu^{\pm} p \gamma$$

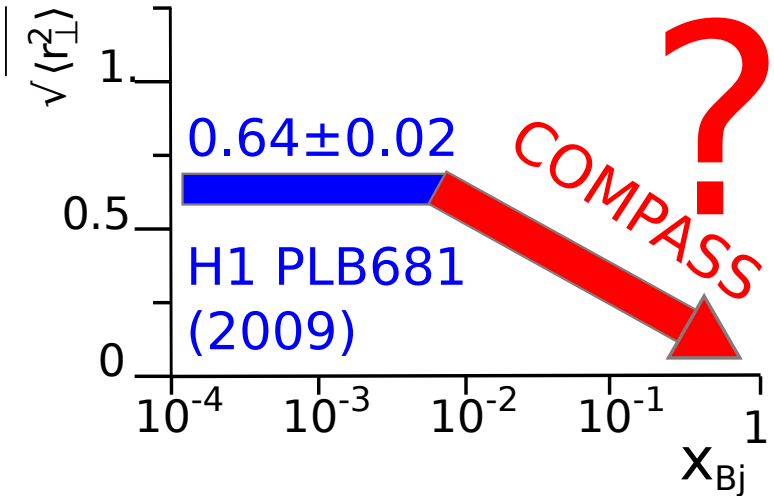


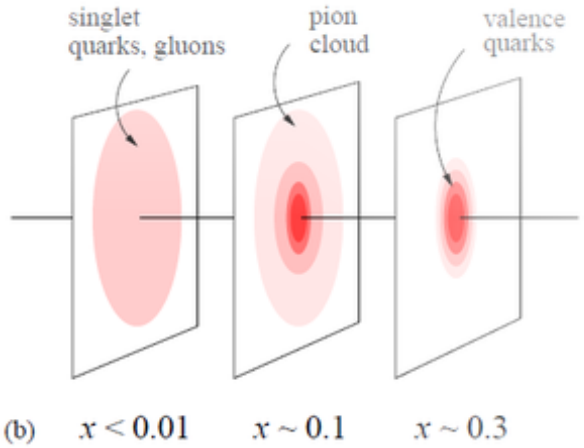
$$S_{CS,U} \equiv d\sigma(\mu^{+\leftarrow}) + d\sigma(\mu^{-\rightarrow}) \propto d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + Ks_1^{Int} \sin\phi$$

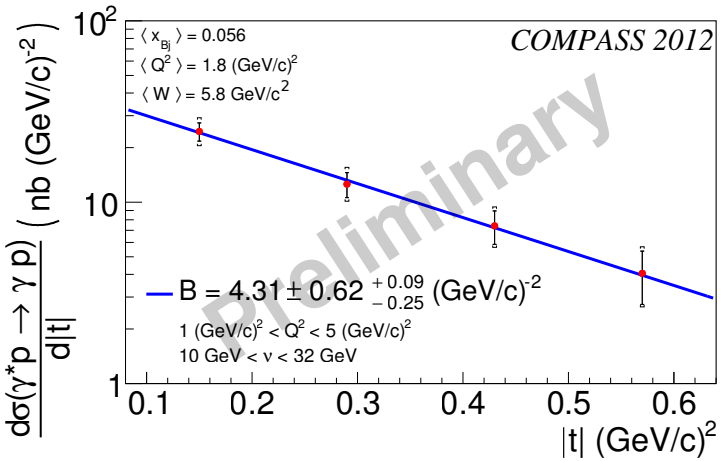
$$\rightarrow d\sigma^{DVCS}/d|t| \sim \exp(-B|t|)$$

$$< r_\perp^2(x_B) > \approx 2B(x_B)$$

$r_\perp \rightarrow$ distance between struck and spectator partons

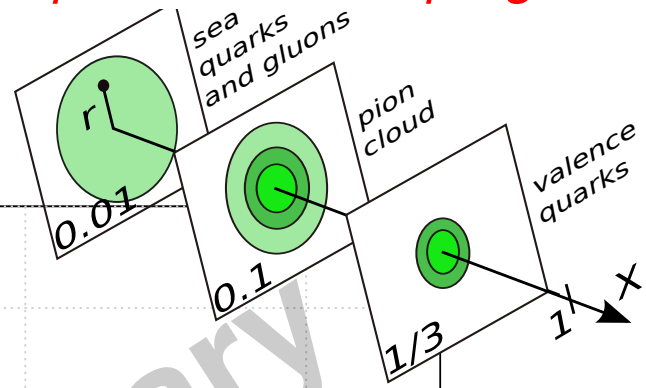


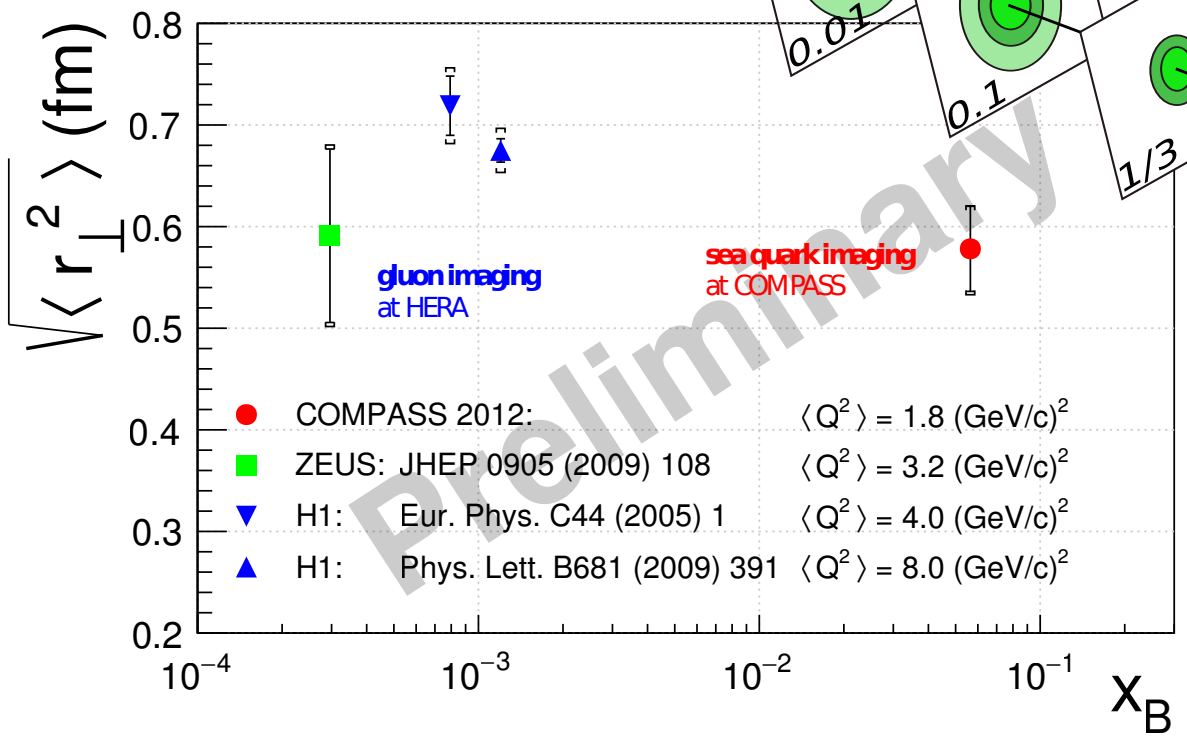




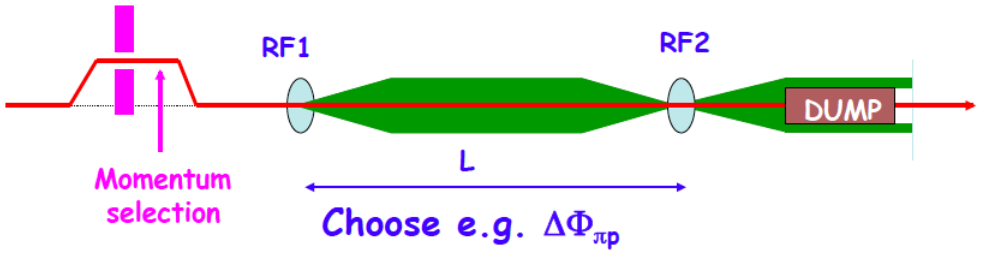
November 2016:
long run part 1 finished

2017: continuation of unpolarised GPD program





- COMPASS has joined the CERN "Physics Beyond Colliders" Working Group



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

- Long-range focus on separated kaon and antiproton beams
  - TMD parton distributions via Drell-Yan
  - direct photon production
  - Strange-meson excitation spectrum, K-γ-reactions
  - $p\bar{p}$ beyond 5 GeV/c^2
- mid-range plans
  - pion DY
  - semi-inclusive DIS, (polarised) DVCS, DVMP (muon beam!)
  - muon-electron scattering for hadronic component (?)
  - hadron spectroscopy
  - dark-matter search (e.g. $\bar{p}$ production c.s.)
- Drafting of a new LoI in 2017

Conclusions

diverse, exciting, long-range physics program

- Inclusive and Semi-inclusive DIS
- Meson Spectroscopy
  - 2008 and 2009: 3π resonances studies with unprecedented precision
  - $>$ 2020 dedicated future Kaon programme with RF-separated beam ($\star$)
- Chiral Dynamics
  - 2012 Primakoff run $\rightarrow$ high-precision α_π, β_π
- Polarised Drell-Yan
  - 2015: successful beam time
  - continued in 2018
- Generalized Parton Distributions
  - 2016 and 2017 $\rightarrow$ GPD H *ongoing*
  - $>$ 2020 polarised target ($\star$) $\rightarrow$ GPD E

Citation: C. Patrignani *et al.* (Particle Data Group), Chin. Phys. C, **40**, 100001 (2016)

$\pi^\pm$ $I^G(J^P) = 1^-(0^-)$

π ELECTRIC POLARIZABILITY α_π

See HOLSTEIN 14 for a general review on hadron polarizability.

VALUE (10^{-4} fm^3)	EVTS	DOCUMENT ID		TECN	COMMENT
2.0±0.6±0.7	63k	[1] ADOLPH	15A	SPEC	$\pi^-\gamma \rightarrow \pi^-\gamma$ Compton scatt.

[1] Value is derived assuming $\alpha_\pi = -\beta_\pi$.

$a_1(1420)$ $I^G(J^{PC}) = 1^-(1^{++})$

OMITTED FROM SUMMARY TABLE

$a_1(1420)$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1414^{+15}_{-13}	[1] ADOLPH	15C	COMP	190 $\pi^- p \rightarrow \pi^-\pi^+\pi^- p$

[1] Using the isobar model and partial-wave analysis with 88 waves.

some of the new COMPASS entries in the RPP2016 edition

($\star$) March 2016: COMPASS "BEYOND 2020" Workshop
`https://indico.cern.ch/event/502879/`
March 2017: IWHSS workshop in Cortona (Toscany)

Thank you for your attention!

Backup

Is Peak in $1^{++}\,0^{+}\,f_0(980)\pi P$ Wave a Model Artifact?

Novel analysis method

(inspired by E791 analysis, PRD **73** (2006) 032204)

- Replace $J^{PC} = 0^{++}$ isobar parametrizations by piece-wise constant amplitudes in $m_{\pi^+\pi^-}$ bins
- Extract $m_{3\pi}$ dependence of 0^{++} isobar amplitude from data
  - Drastic reduction of model bias
  - *Caveat:* significant increase in number of fit parameters
- Result: the $a_1(1420)$ signal is indep. on the $f_0(980)$ description