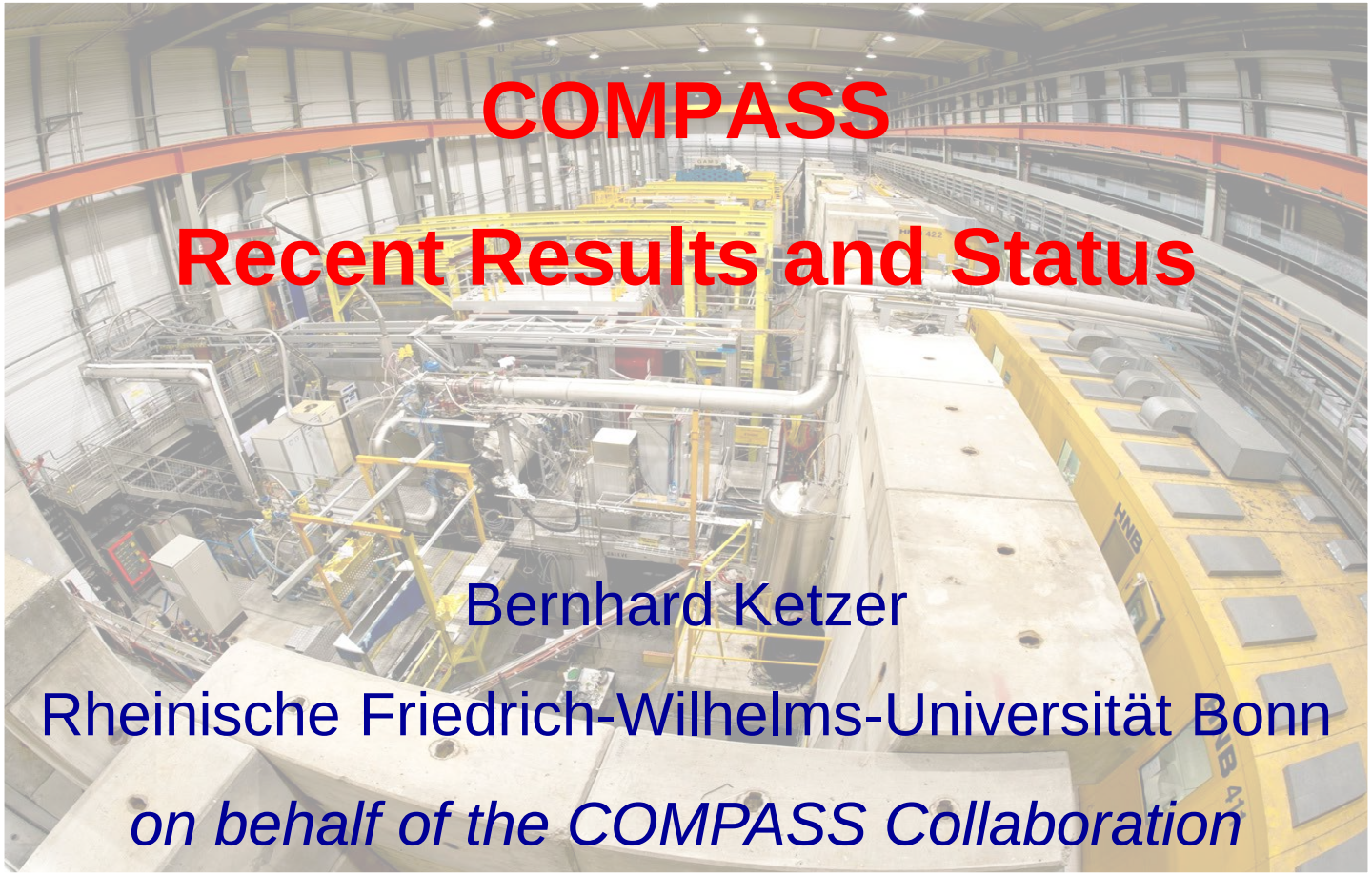


COMPASS

Recent Results and Status

Bernhard Ketzer

Rheinische Friedrich-Wilhelms-Universität Bonn

on behalf of the COMPASS Collaboration

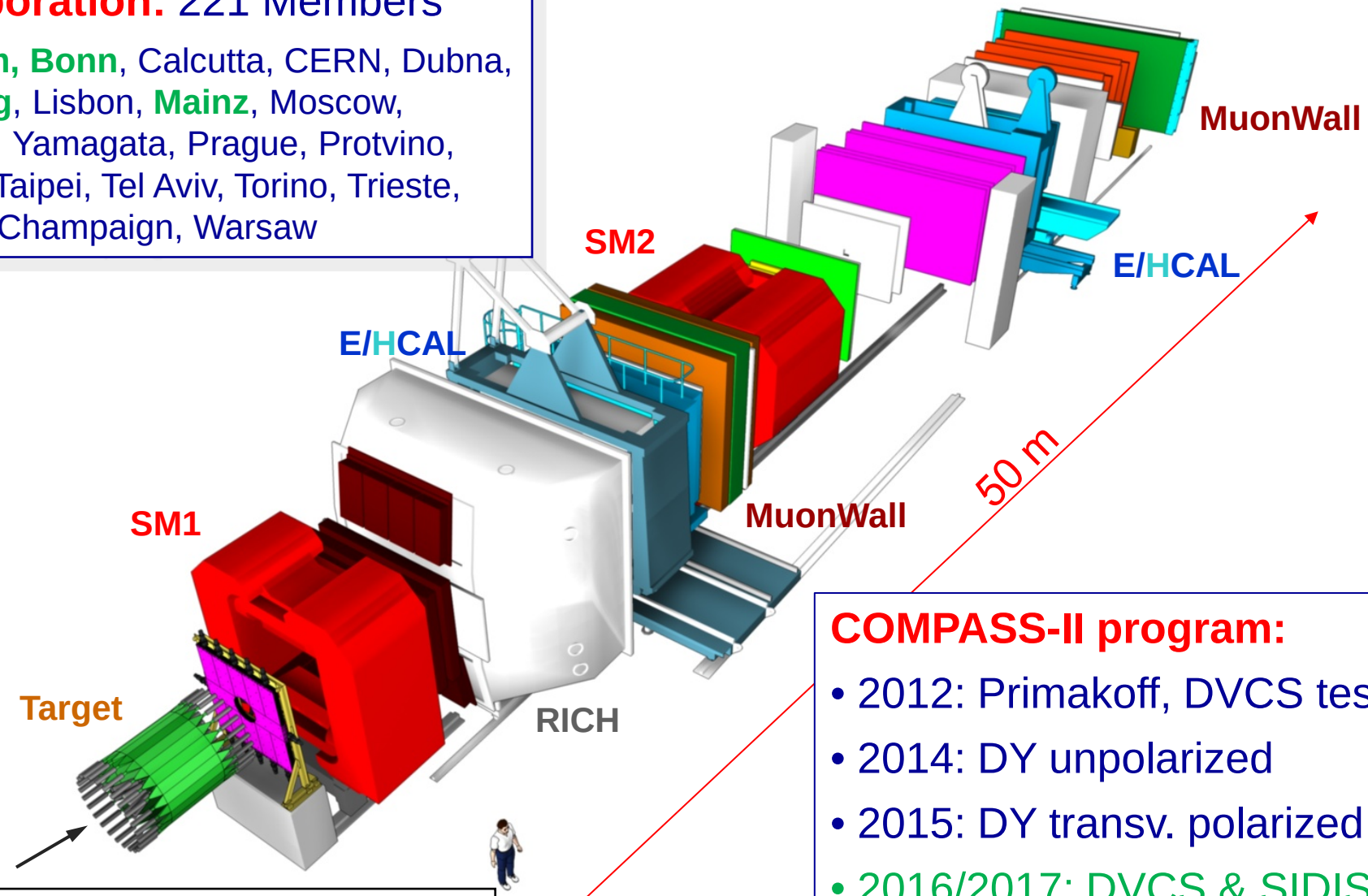
Bad Honnef
5 December 2015

bmb+f - Förderschwerpunkt
COMPASS
Großgeräte der physikalischen Grundlagenforschung

The COMPASS Experiment

Collaboration: 221 Members

Bochum, Bonn, Calcutta, CERN, Dubna, **Freiburg**, Lisbon, **Mainz**, Moscow, **Munich**, Yamagata, Prague, Protvino, Saclay, Taipei, Tel Aviv, Torino, Trieste, Urbana-Champaign, Warsaw



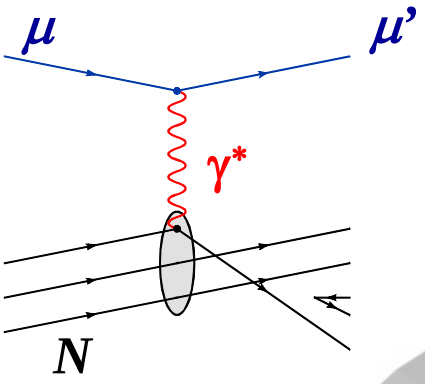
[COMPASS, P. Abbon et al., NIM A 779, 69 (2015)]

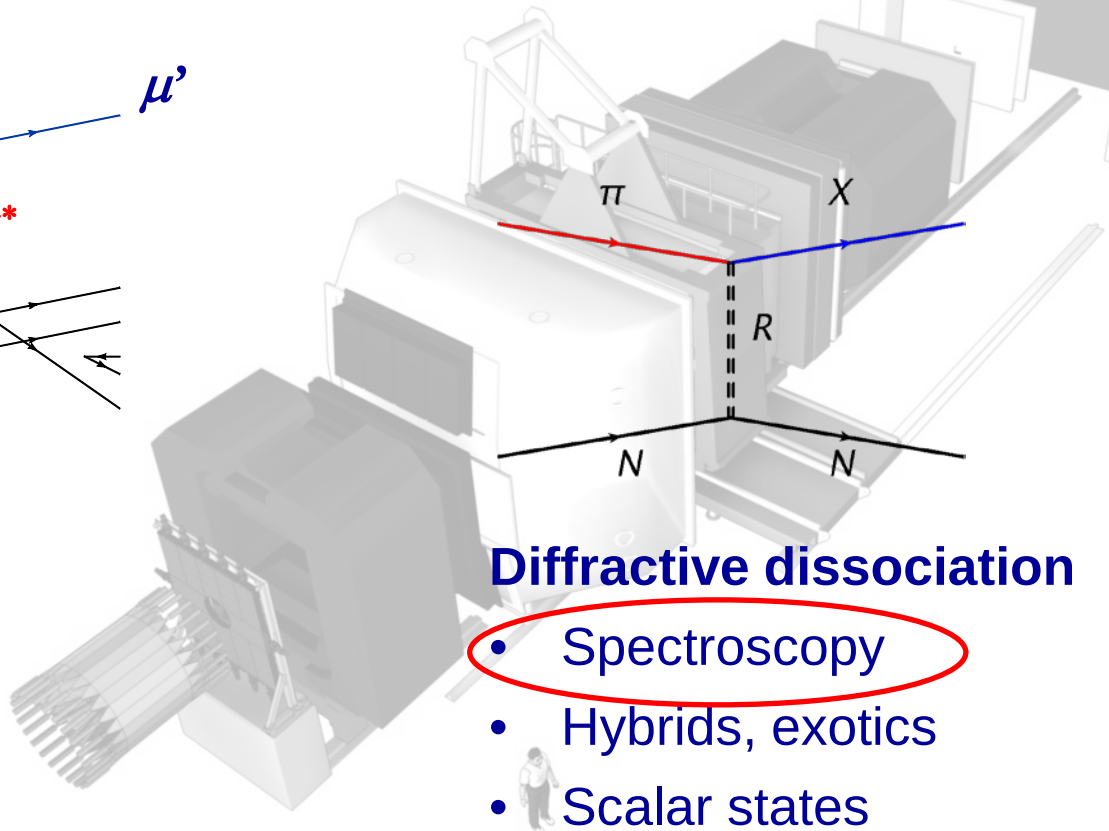
COMPASS-II program:

- 2012: Primakoff, DVCS test
- 2014: DY unpolarized
- 2015: DY transv. polarized
- 2016/2017: DVCS & SIDIS

Hard e.m. processes

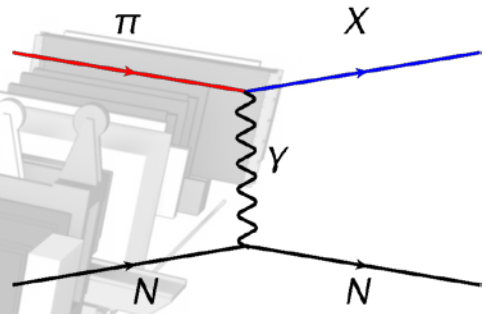
- Spin structure
- TMDs
- GPDs





Diffractive dissociation

- Spectroscopy
- Hybrids, exotics
- Scalar states

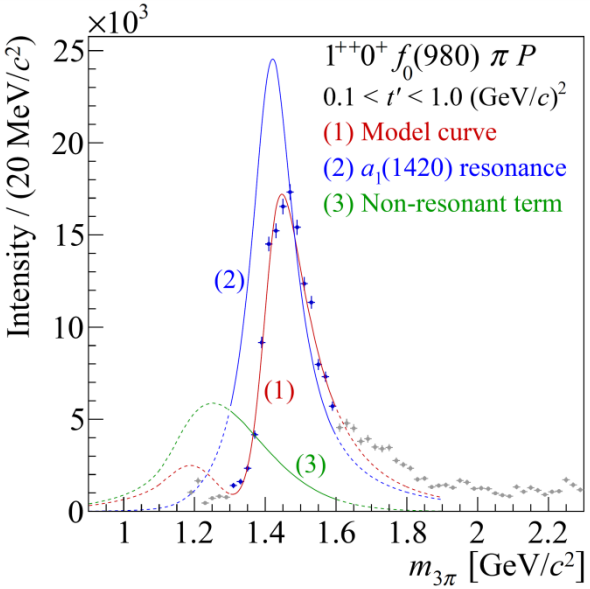


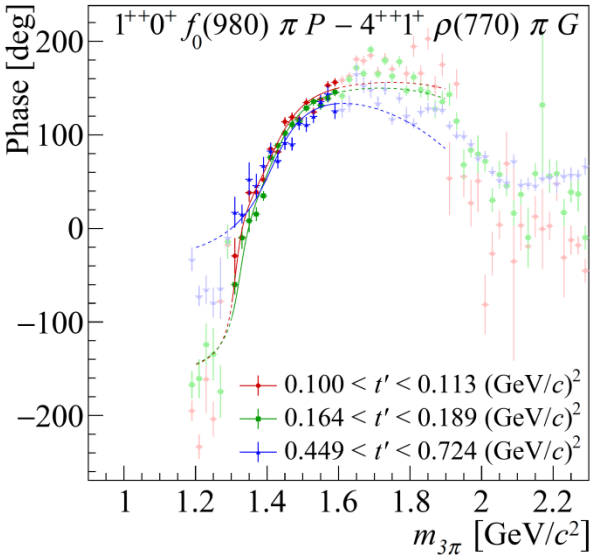
Photoproduction

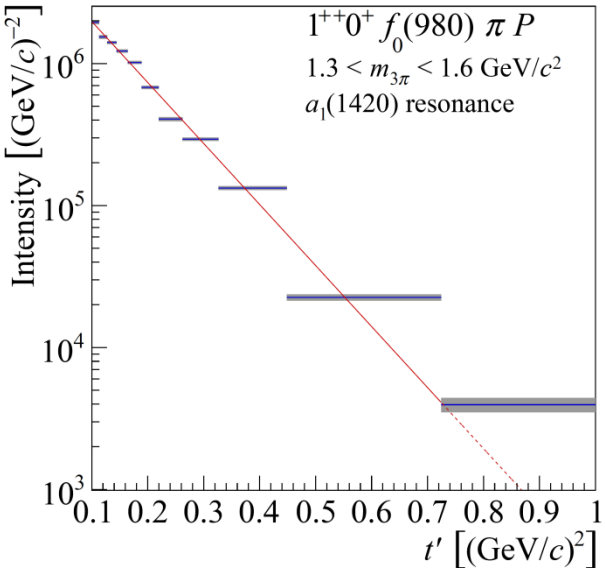
- Polarizabilities: π
- Spectroscopy

New $a_1(1420)$

$$\pi^- + p \to 3\pi + p$$







- Data described well by Breit-Wigner and non-resonant background
- Parameters for BW:

$$M_0 = 1414^{+15}_{-13}\ \text{MeV/c}$$

$$\Gamma_0 = 153^{+8}_{-23}\ \text{MeV}/c$$

[C. Adolph et al., COMPASS, PRL 115, 082001 (2015)]

Press Echo

Science Ticker

Particle Physics

New particle may be made of four quarks

By Andrew Grant 4:48pm, February 2, 2015

CERN's COMPASS

Das Physikportal pro-physik.de

Exotischer Teilchenzustand gibt Rätsel auf

01. September 2015

COMPASS-Kollaboration am CERN entdeckt neues Meson aus leichten Quarks

Eine exotische Kombination von leichten Quarks haben Wissenschaftler der COMPASS-Kollaboration am CERN beobachtet. Die Entdeckung gelang bei

scinexx.de

Das Wissensmagazin

Rubriken | Freitag

Exotischer Teilchenzustand gibt Rätsel au

Neu entdecktes Zerfallsprodukt lässt sich nach gä
Physik nicht erklären

Physikalisches Rätsel: Forscher des CERN h
im Teilchenbeschleuniger ein unbekanntes
Teilchen entdeckt. Noch ist unklar, ob es si
eine exotische Kombination aus zwei Meso
ein Partikel aus vier Quarks handelt. Klar is
dagegen, dass bisherige theoretische Erklär
das Verhalten dieses Teilchens nicht ausrei
beschreiben. Ein Physiker bezeichnete es da
"neues Mitglied im Club der bisher unerklärt
Zustände".

MOTHERBOARD

Videos | Maschinen | Politik | Zukunft | Natur | Kultur | Entdeckungen

CERN entdeckt neues Teilchen für den „Club der unerklärten Zustände"

1 September 2015 // 09:31 AM CET

Autor
CHRISTINE KEWITZ
REDAKTEURIN

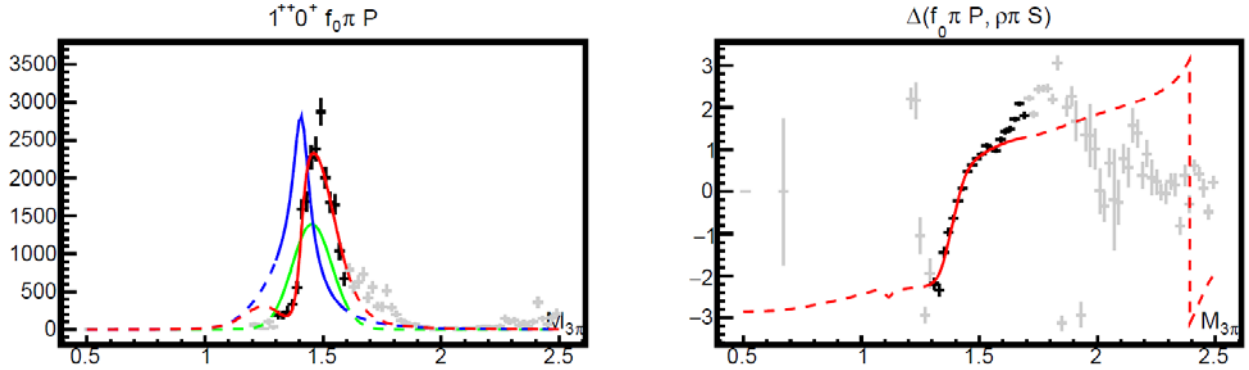
Ist es nicht schön, wenn man nach jahrelanger Partnerschaft noch unbekannte, aufregende Seiten an seinem Lebensgefährten entdeckt? So ähnlich muss es den Physikern des CERN, gegangen sein, die in einem schon sehr gut untersuchten Massebereich überraschenderweise ein neues Teilchen entdeckten.

Dem Standardmodell der Elementarteilchenphysik zufolge, welches alle bekannten Teilchen und ihre Wechselwirkungen aufführt, sind Quarks die fundamentalen

CONNECT TO MOTHERBOARD

Nature of new Structure?

- 4-quark state candidate [Z.-G. Wang, arXiv:1401.1134], [H.-X.Chen, PRD 91, 094022 (2015)]
- K^*K molecule (similar to X(3872) interpretation)
- Interference of Deck $\rho\pi$ S and $f_0\pi$ P-wave [J.-L. Basdevant et al., PRL 114, 192001 (2015)]
- Triangle singularity [M. Mikhasenko, BK, A. Sarantsev, PRD 91, 094015 (2015)]

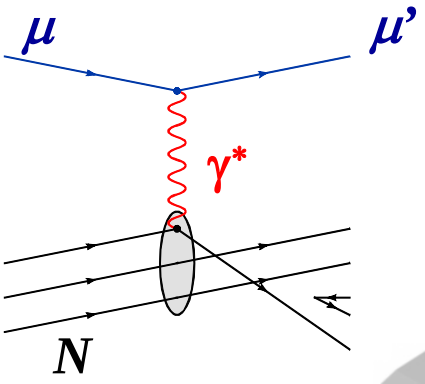


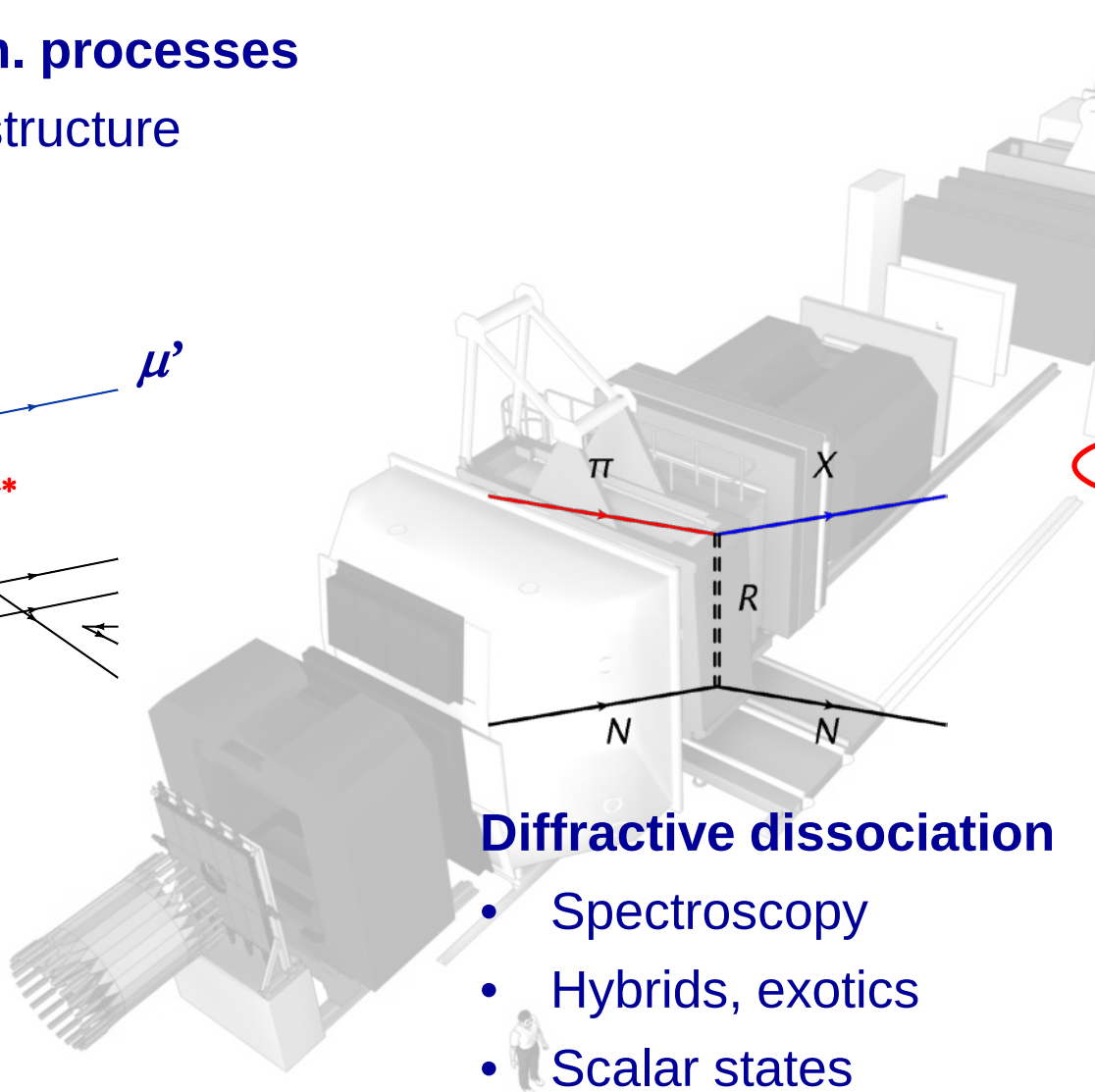
  - Decay of $a_1(1260) \rightarrow K^*\bar{K}$ above threshold
  - Final state rescattering of $K\bar{K}$ to $f_0(980)$

    ⇨ logarithmic singularity of amplitude if particles close to mass shell

Hard e.m. processes

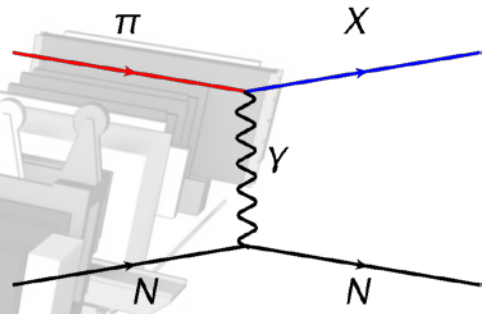
- Spin structure
- TMDs
- GPDs





Diffractive dissociation

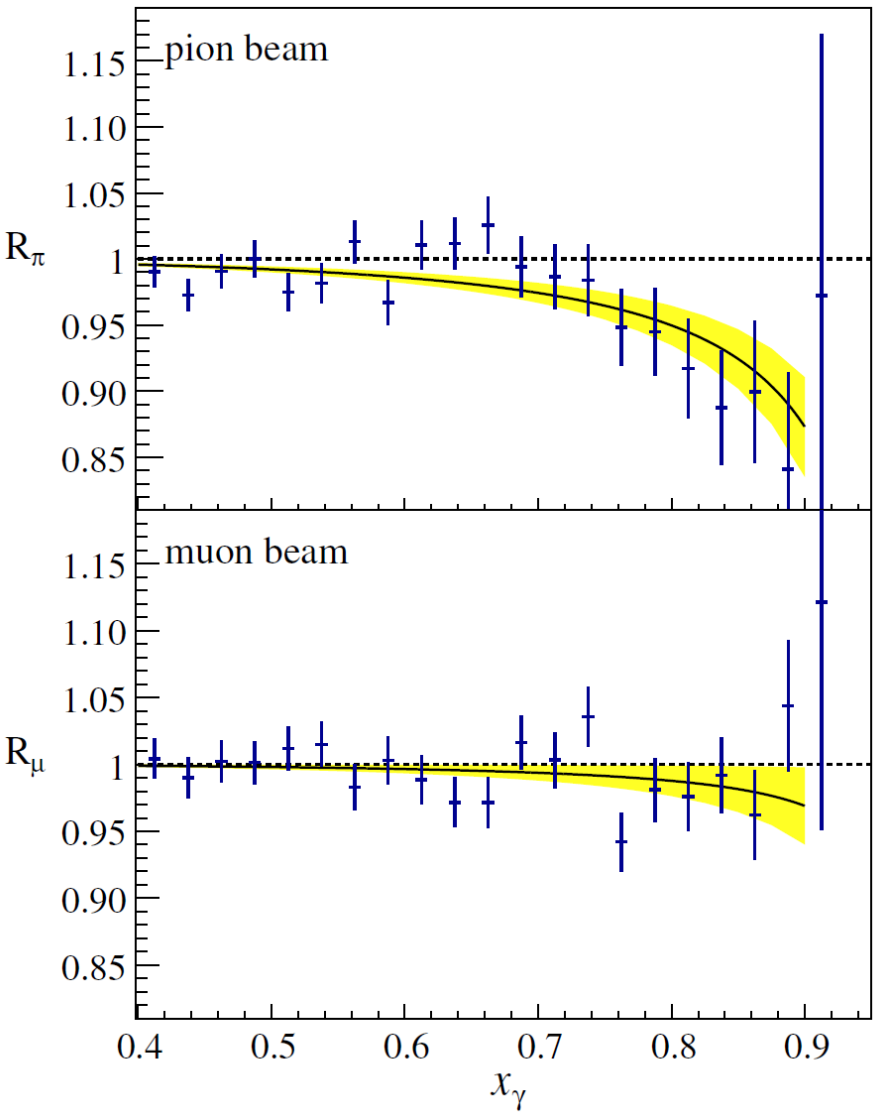
- Spectroscopy
- Hybrids, exotics
- Scalar states



Photoproduction

- Polarizabilities: π
- Spectroscopy

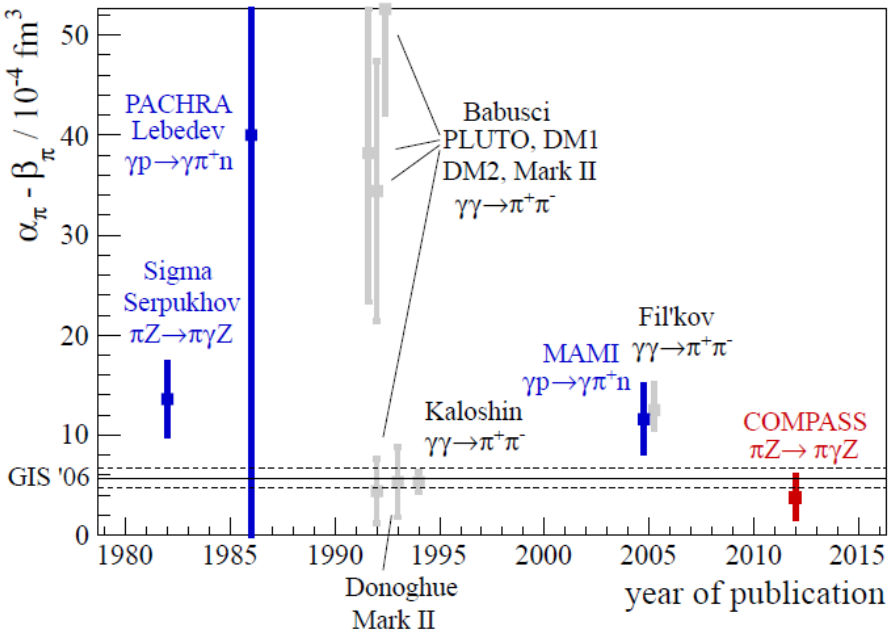
Pion Polarizability



[C. Adolph et al., PRL 114, 062002 (2015)]

New COMPASS result (2009 data):

$$\alpha_\pi = (2.0 \pm 0.6_{\text{stat}} \pm 0.7_{\text{syst}}) \times 10^{-4}\ \text{fm}^3$$

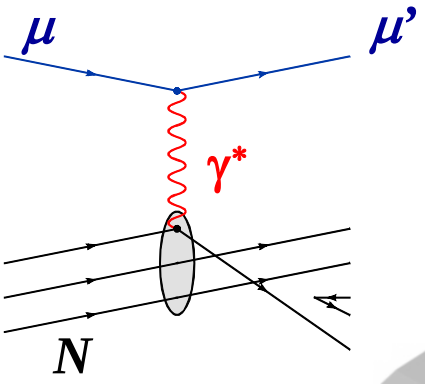


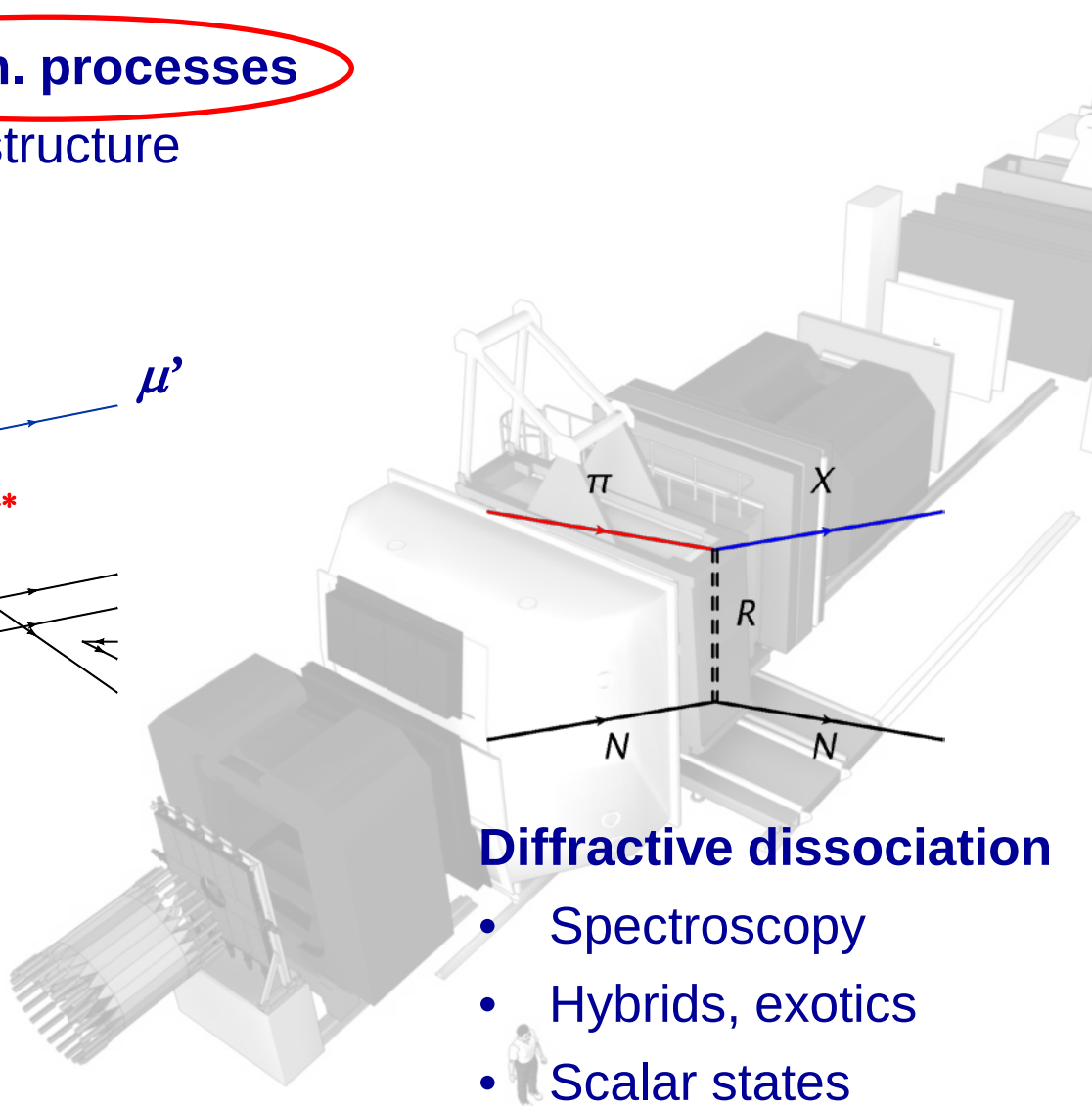
2012 Run:

- 5× more data
- Improved trigger (**TUM**)

Hard e.m. processes

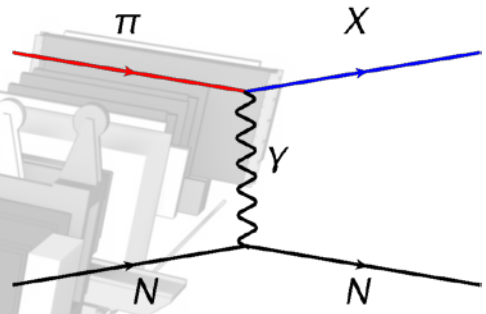
- Spin structure
- TMDs
- GPDs





Diffractive dissociation

- Spectroscopy
- Hybrids, exotics
- Scalar states



Photoproduction

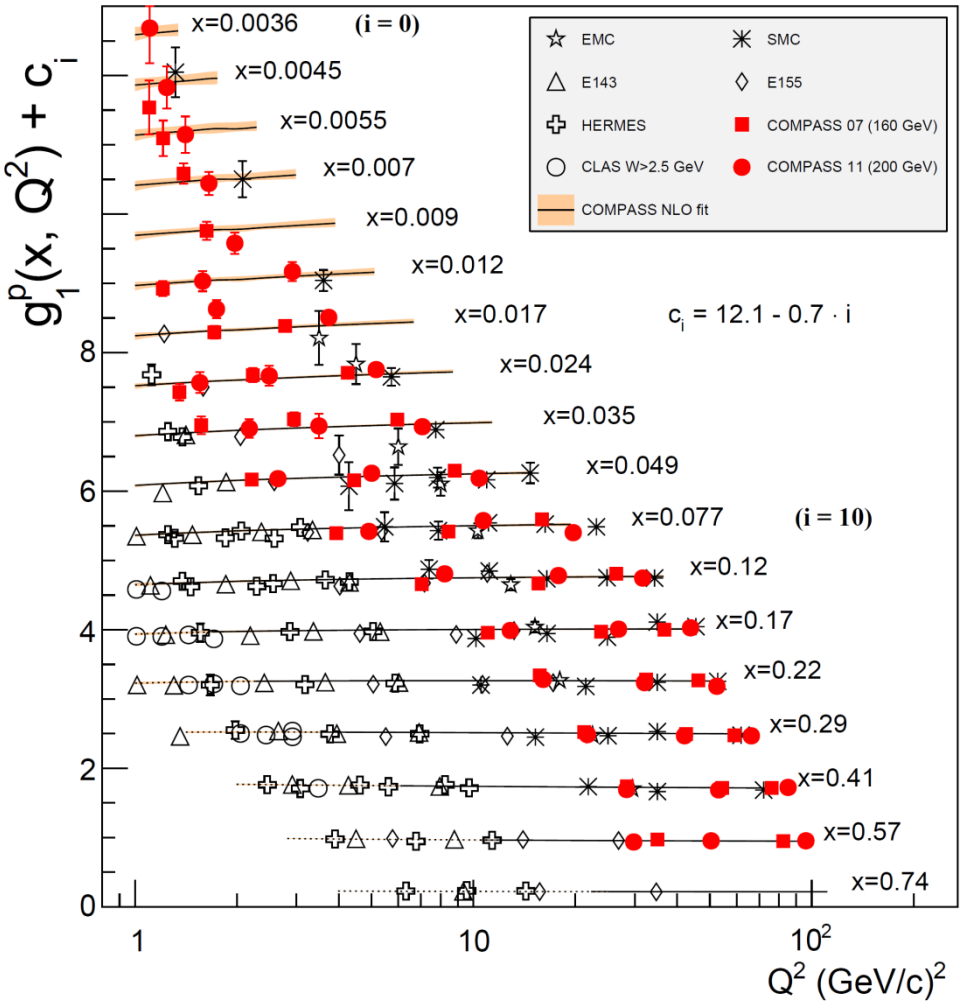
- Polarizabilities: π
- Spectroscopy

Proton Spin Structure

- Full COMPASS data set on p, d
- COMPASS NLO fit to world data

First moment	Value range at $Q^2 = 3\,(\mathrm{GeV}/c)^2$
$\Delta\Sigma$	[0.26 , 0.36]
$\Delta u + \Delta\bar{u}$	[0.82 , 0.85]
$\Delta d + \Delta\bar{d}$	[−0.45 , −0.42]
$\Delta s + \Delta\bar{s}$	[−0.11 , −0.08]

- Gluon contribution small but not strongly constrained

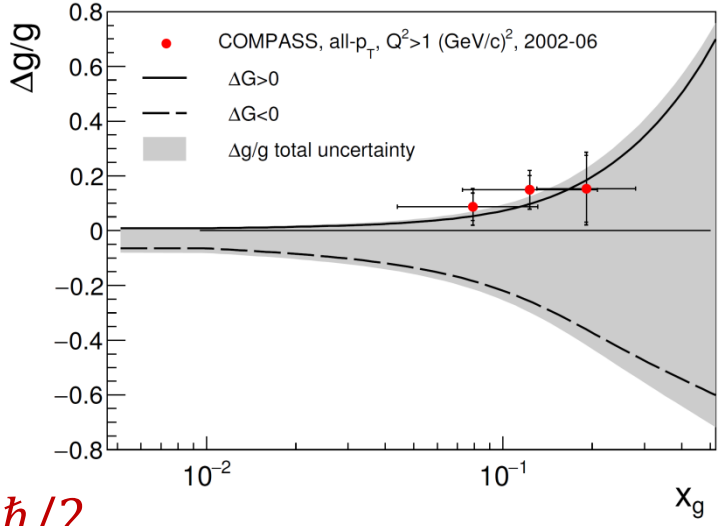


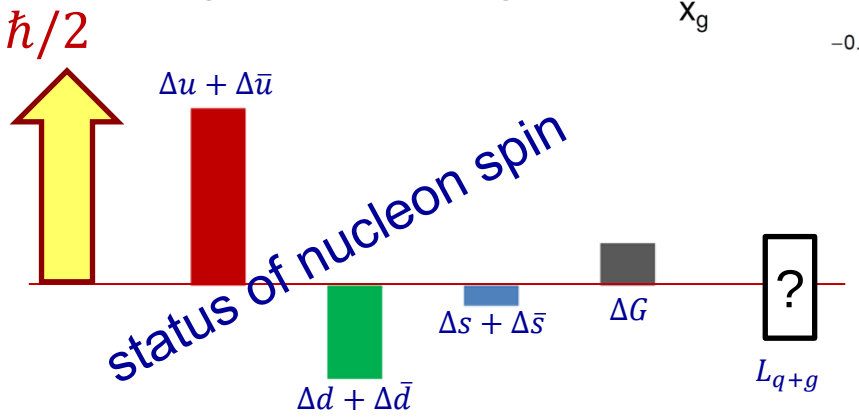
[C. Adolph et al., subm. PLB, hep-ex/1503.08935 (2015)]

Gluon Contribution

Leading hadrons (all p_T):

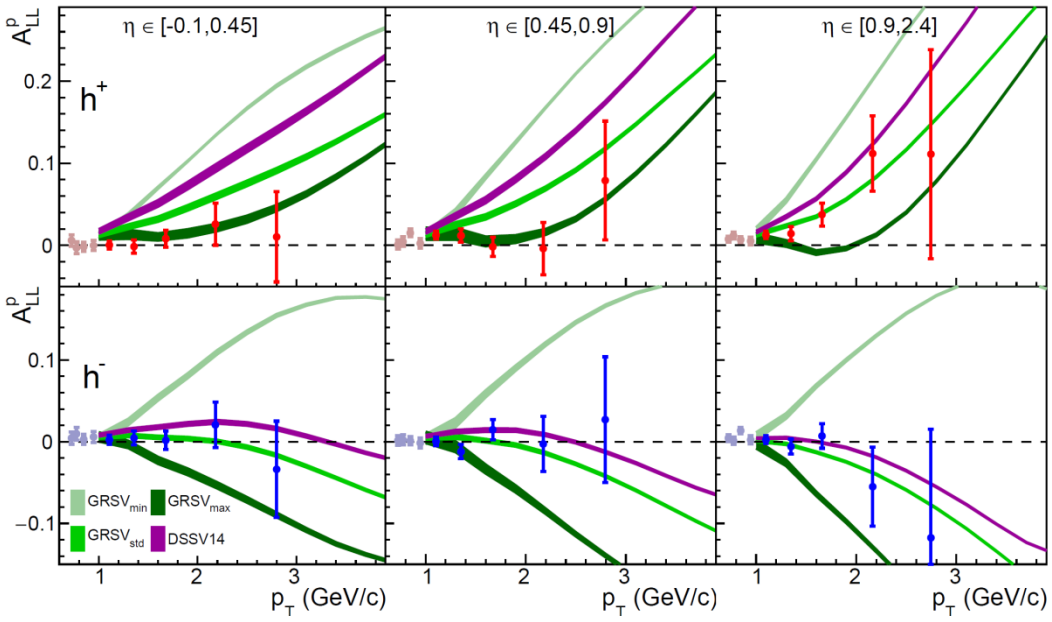
- LO analysis
- Compared to NLO fit





Single-inclusive hadron production:

- NLO analysis
- Theory: W. Vogelsang et al.



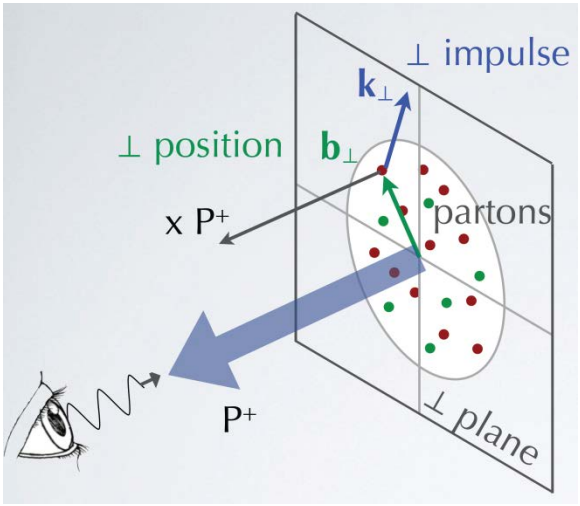
⇨ $\Delta G > 0$ favored

[C. Adolph et al., subm. PLB, hep-ex/1503.03526 (2015)]

Imaging of the Proton

Full information: Wigner distributions (5D)

- Correlation of quark $k_\perp$, $b_\perp$ and x as function of N and q polarization
- Projections have probabilistic interpretation



$W(x, b_T, k_T)$
Wigner distributions

$\int d^2 b_T$ $\int d^2 k_T$

$f(x, k_T)$
transverse momentum distributions (TMDs)
semi–inclusive processes

$f(x, b_T)$
impact parameter distributions

Fourier trf.
$b_T \leftrightarrow \Delta$

$H(x,0,t)$
$t = -\Delta^2$

$\xi = 0$

$H(x,\xi,t)$
generalized parton distributions (GPDs)
exclusive processes

$\int d^2 k_T$ $\int d^2 b_T$

$f(x)$
parton densities
inclusive and semi–inclusive processes

$\int dx$

$F_1(t)$
form factors
elastic scattering

$\int dx x^{n-1}$

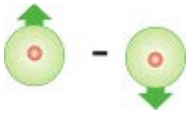
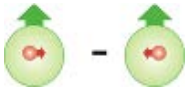
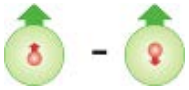
$A_{n,0}(t) + 4\xi^2 A_{n,2}(t) + \ldots.$
generalized form factors
lattice calculations

[A. Accardi et al., arXiv:1212.1701 (2014)]

3D-Imaging in Momentum Space

nucleon polarisation

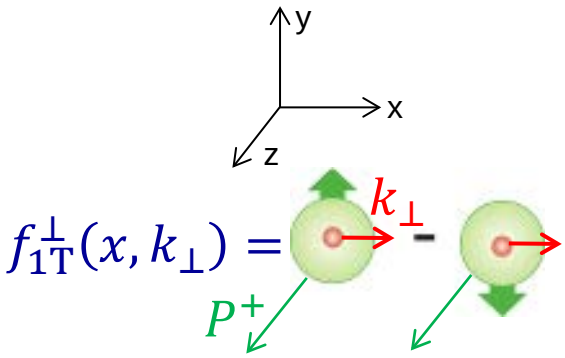
quark polarisation

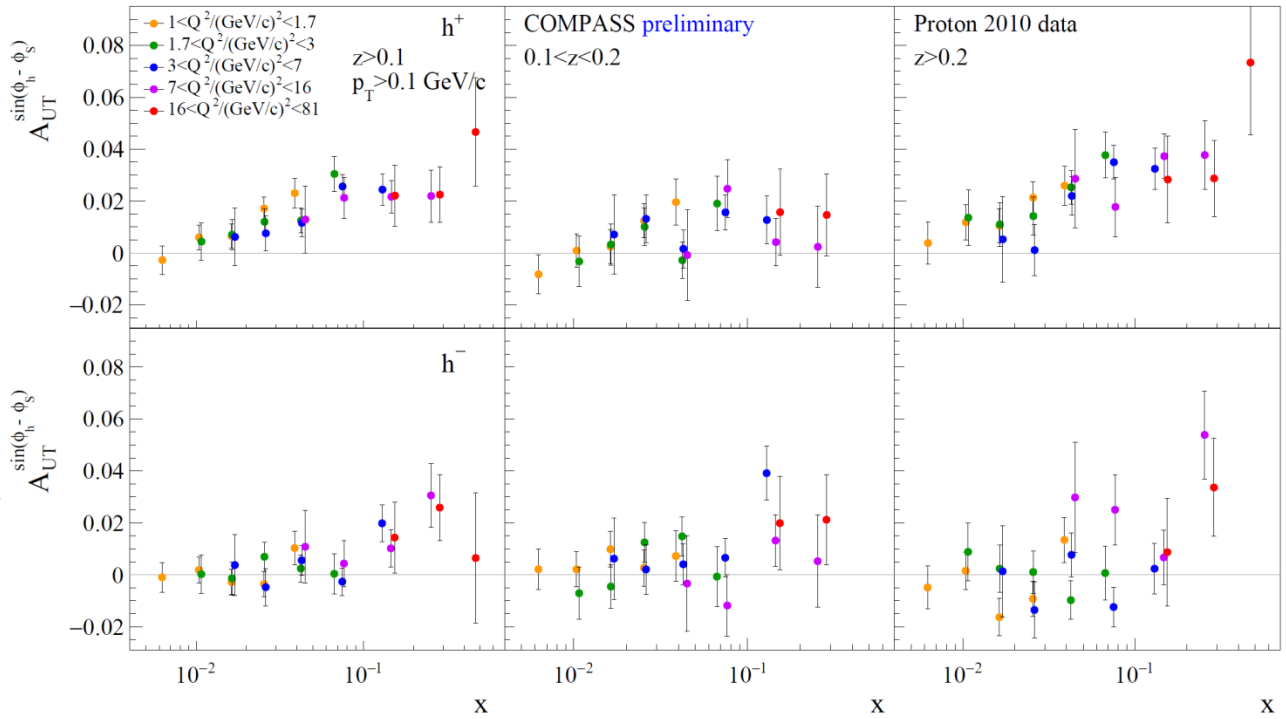
	U	L	T	
U	f_1  q ***momentum***		$f_{1T}^{\perp}$  ***Sivers***	$\Delta_0^T q$
L		g_1  ***helicity*** Δq	g_{1T} 	
T	$h_1^{\perp}$  ***Boer Mulders***	$h_{1L}^{\perp}$ 	h_1  ***transversity*** $h_{1T}^{\perp}$ 	$\Delta_T q$

- 3 PDFs which survive integration over k_T
- 8 PDFs with quark intrinsic k_T :Transverse-Momentum Distributions

Polarized TMD: Sivers Effect

Multidimensional analysis of 8 TMDs in bins of (x, z, p_T, Q^2)





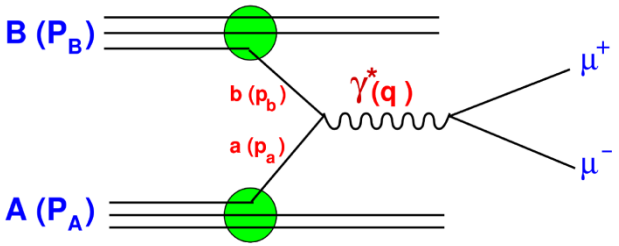
- Sivers effect ⇔ distortion of parton transverse momentum distribution due to N polarization
- Needs orbital angular momentum
- QCD predicts sign change of T-odd TMDs

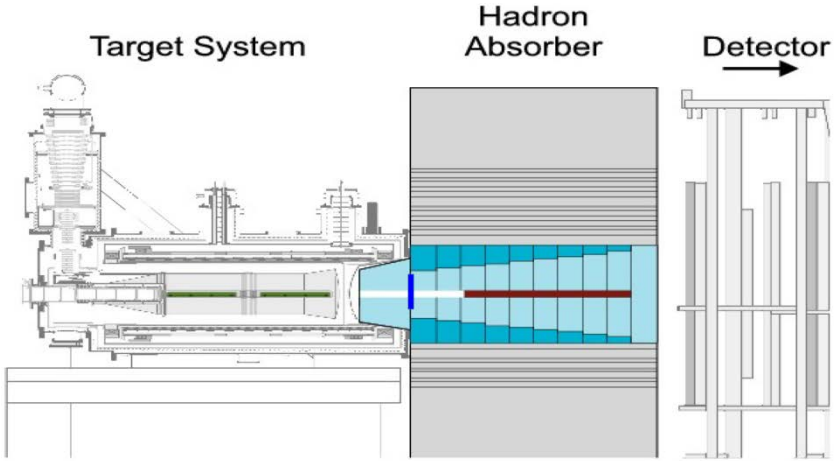
$$f_{1T}^{\perp}\big|_{\text{SIDIS}} = -\, f_{1T}^{\perp}\big|_{\text{DY}}$$

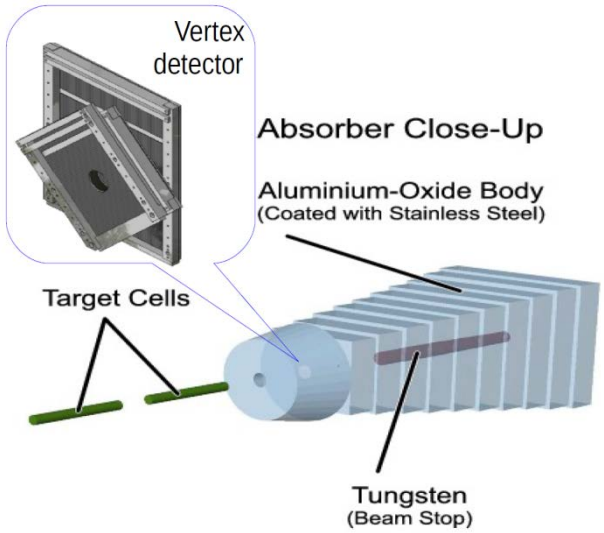
COMPASS is the only experiment which can do both with the same setup!

Drell-Yan

- Pion beam: $\bar{u}_v^{\pi} + u_v^{p}$ $\quad d\sigma^{DY} \propto f_{\bar{u}}^{\pi} \otimes f_{u}^{p}$
- 190 GeV/c π beam: 10^8 / s
- Transv. polarized NH_3 target (Bochum)
- Hadron absorber







- New SciFi vertex detector (Bonn HISKP)
- Dimuon trigger system (Bonn PI, Mainz)
- DAQ upgrade (TUM)

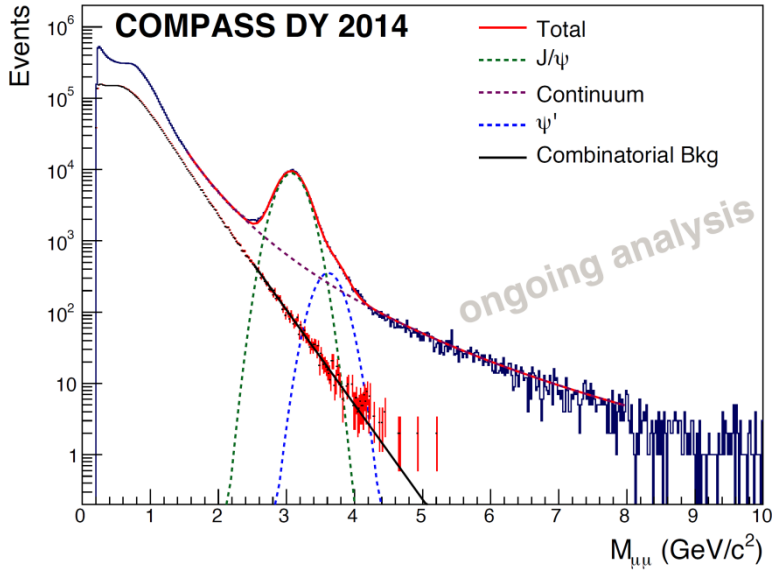
Drell-Yan Run 2014/2015

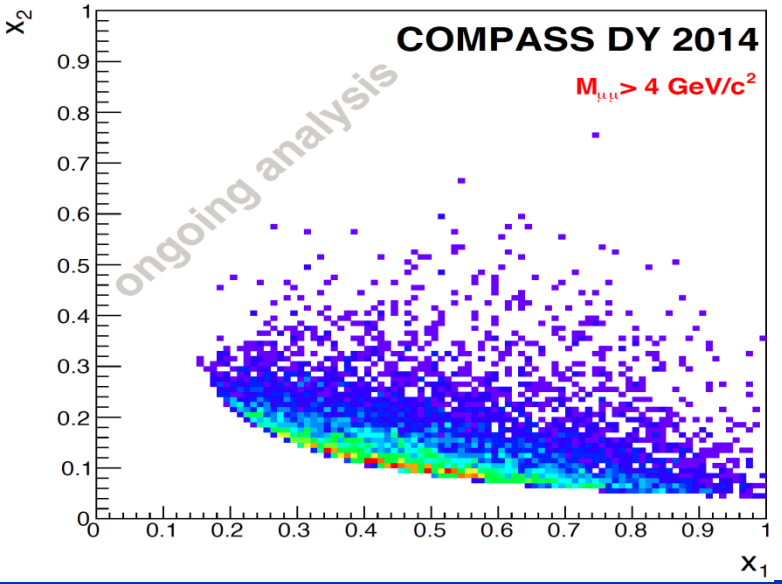
2014: 3 week pilot run, unpolarized

2015: 4.5 months, transv. polarized target ($P_T \approx 80\%$)

Statistics:

	Data	# ev. $M_{J/\psi}$	# ev. $M > 4$ GeV
2014	140 TB	250 k	8 k
2015	740 TB	2.7 M	80 k





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Statistics:

	Data	# ev. $M_{J/\psi}$	# ev. $M > 4$ GeV
2014	140 TB	250 k	8 k
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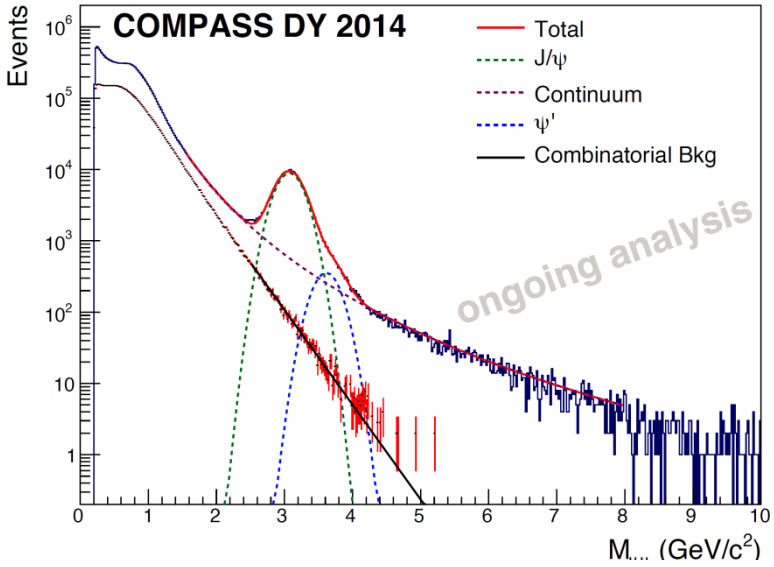
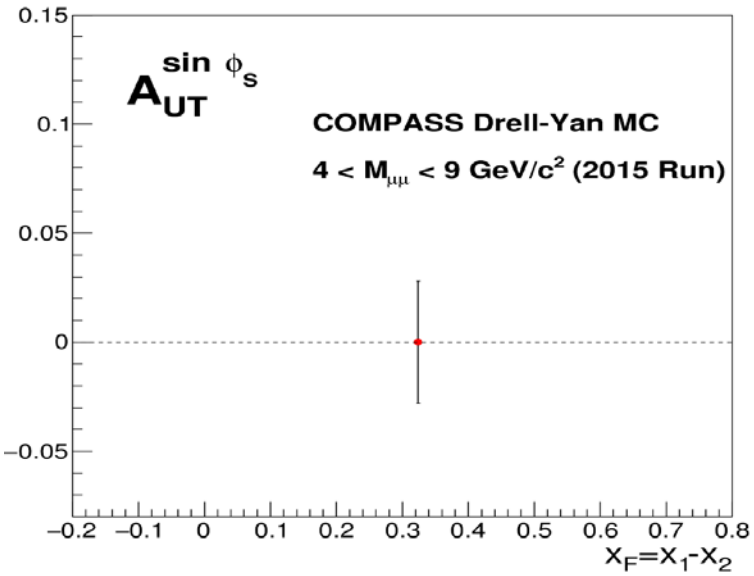
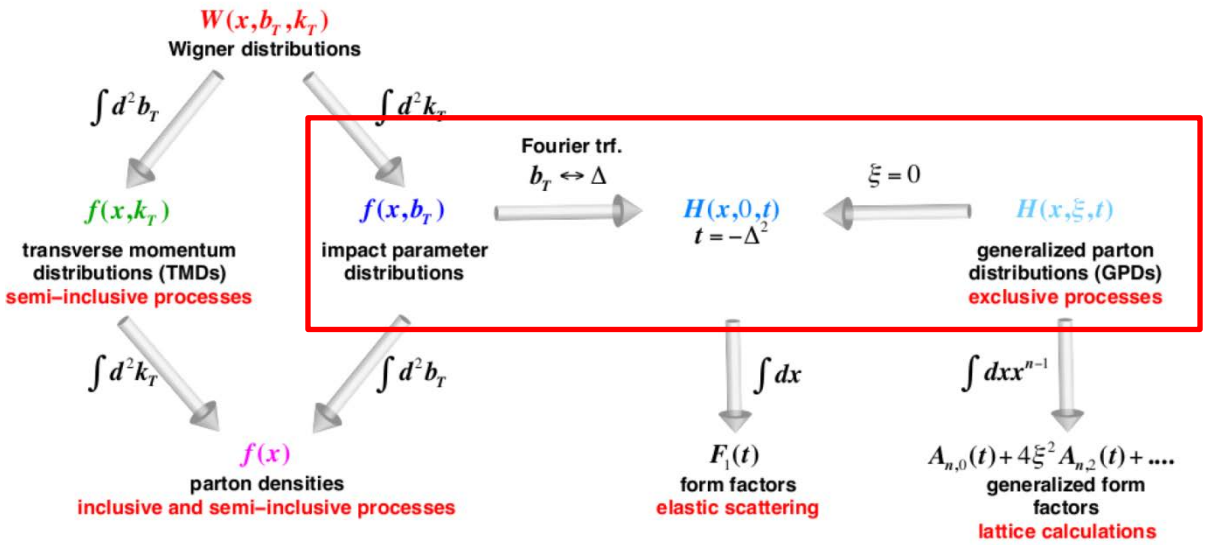
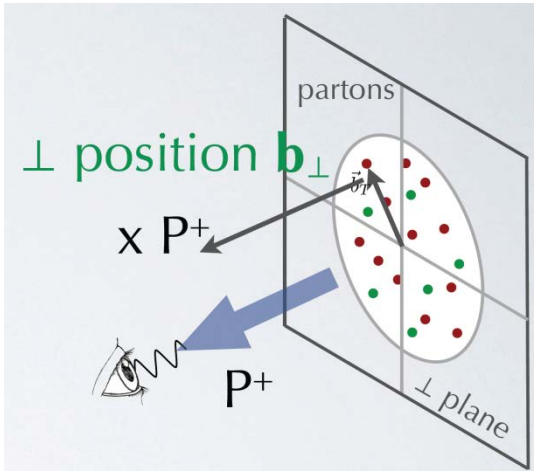
Expected statistical error on Sivers asym.: 2.8%





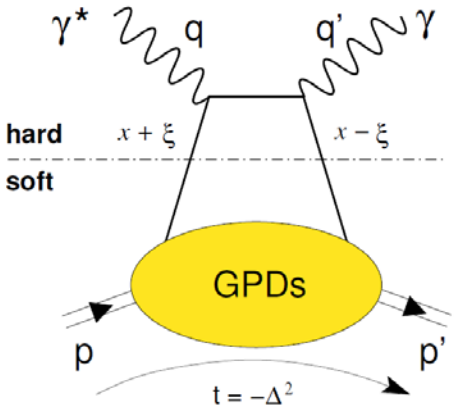
3D-Imaging in Configuration Space





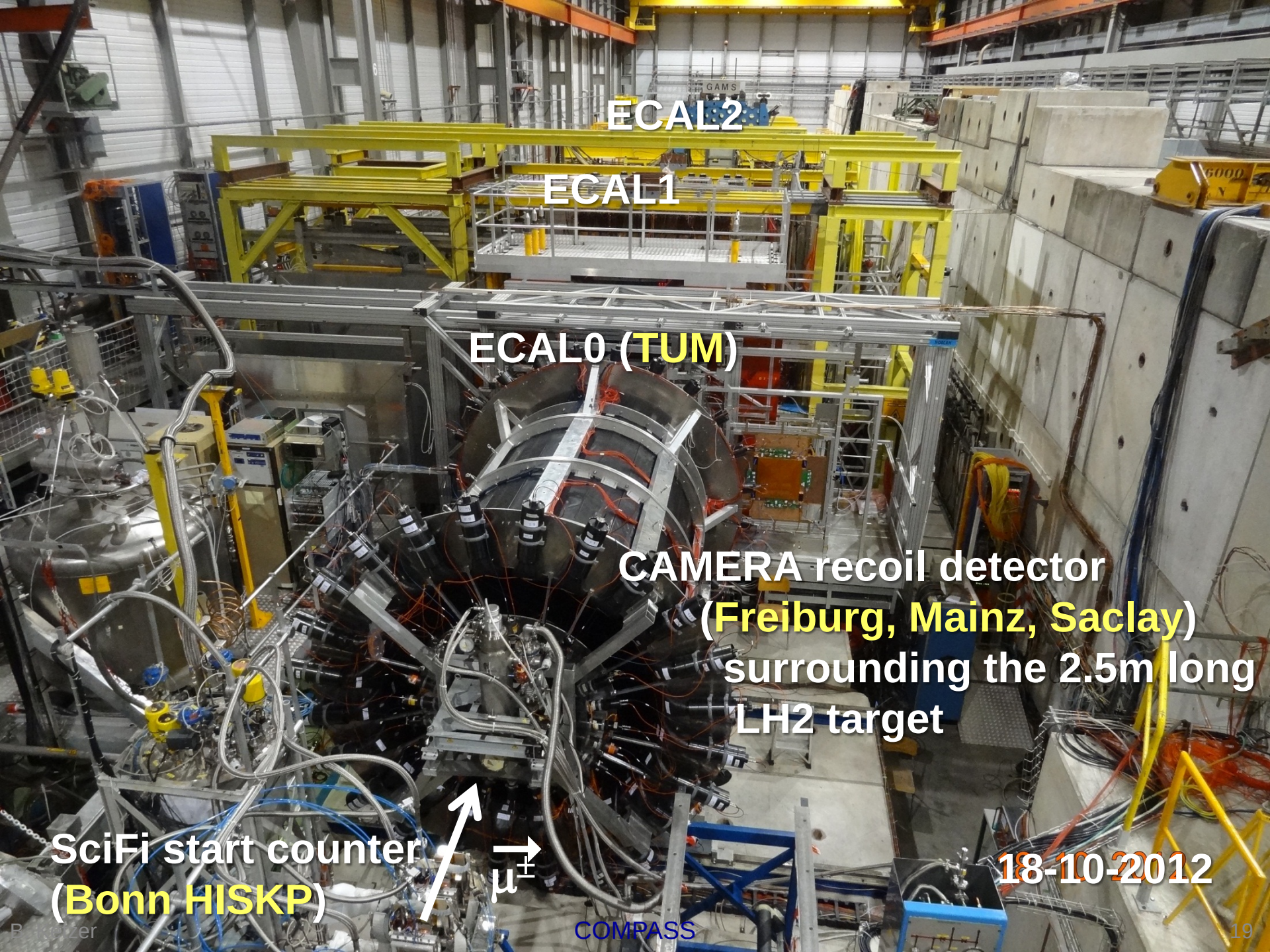
Generalized Parton Distributions $H, \tilde{H}, E, \tilde{E}(x,\xi,t,Q^2)$

longitudinal parton momentum x
vs transverse coordinate $b_\perp$

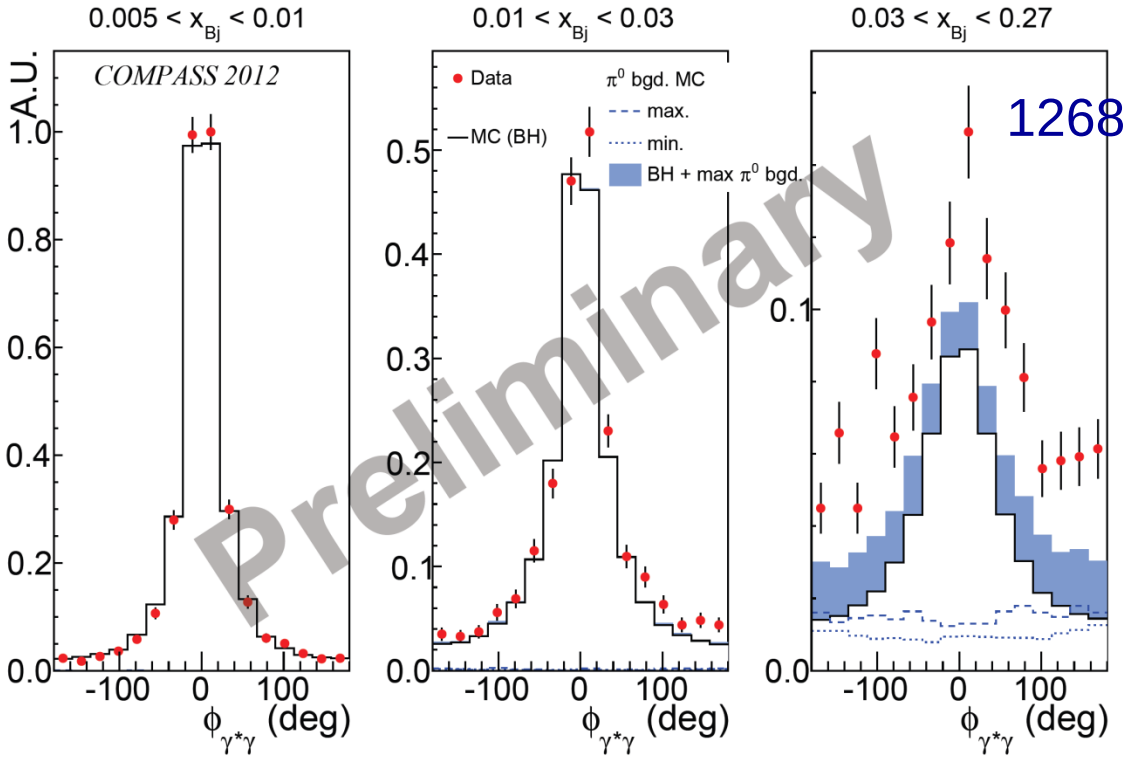


Experiment: DVCS and HEMP

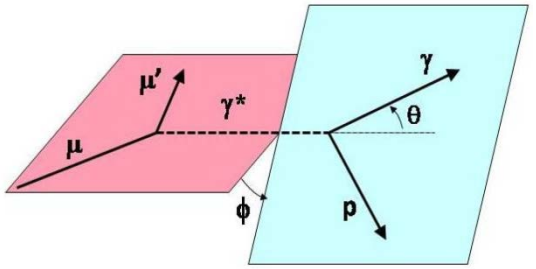
- 3-D image of partonic structure of the nucleon
- Unpolarized target ⇨ H
- Transversely polarized target ⇨ E


ECAL2
ECAL1
ECAL0 (TUM)
CAMERA recoil detector
(Freiburg, Mainz, Saclay)
surrounding the 2.5m long
LH2 target
SciFi start counter
(Bonn HISKP)
$\vec{\mu}^{\pm}$
18-10-2012

DVCS Test Run 2012



1268 events



- Exclusive events selected based on azimuthal angle and transv. momentum
- Main background: γ from π_0, estimated by MC
- Analysis of t- dependence of pure DVCS contribution ongoing
- 2016/2017: DVCS run with 190 GeV μ^+, μ^- beam

Conclusions

- COMPASS: laboratory for precision studies of strong interaction
  - Fresh view on light meson spectrum: PWA, dynamics
  - Low-energy limit of QCD, chiral PT studies
  - From 1D to 3D picture of nucleon: TMDs and GPDs
  - Strong collaboration with theory colleagues
- Primakoff run in 2012
- DY run in 2014/2015
- Now preparing for DVCS run in 2016/2017
- Extension for 2018 being prepared: DY, spectroscopy

- Long-term perspectives:
  - ⇨ DVCS with transv. pol. target, DY flavor sep., TMD evolution
  - ⇨ Spectroscopy of strange mesons, Primakoff reactions
  - ⇨ Workshop in 2016 on further possibilities