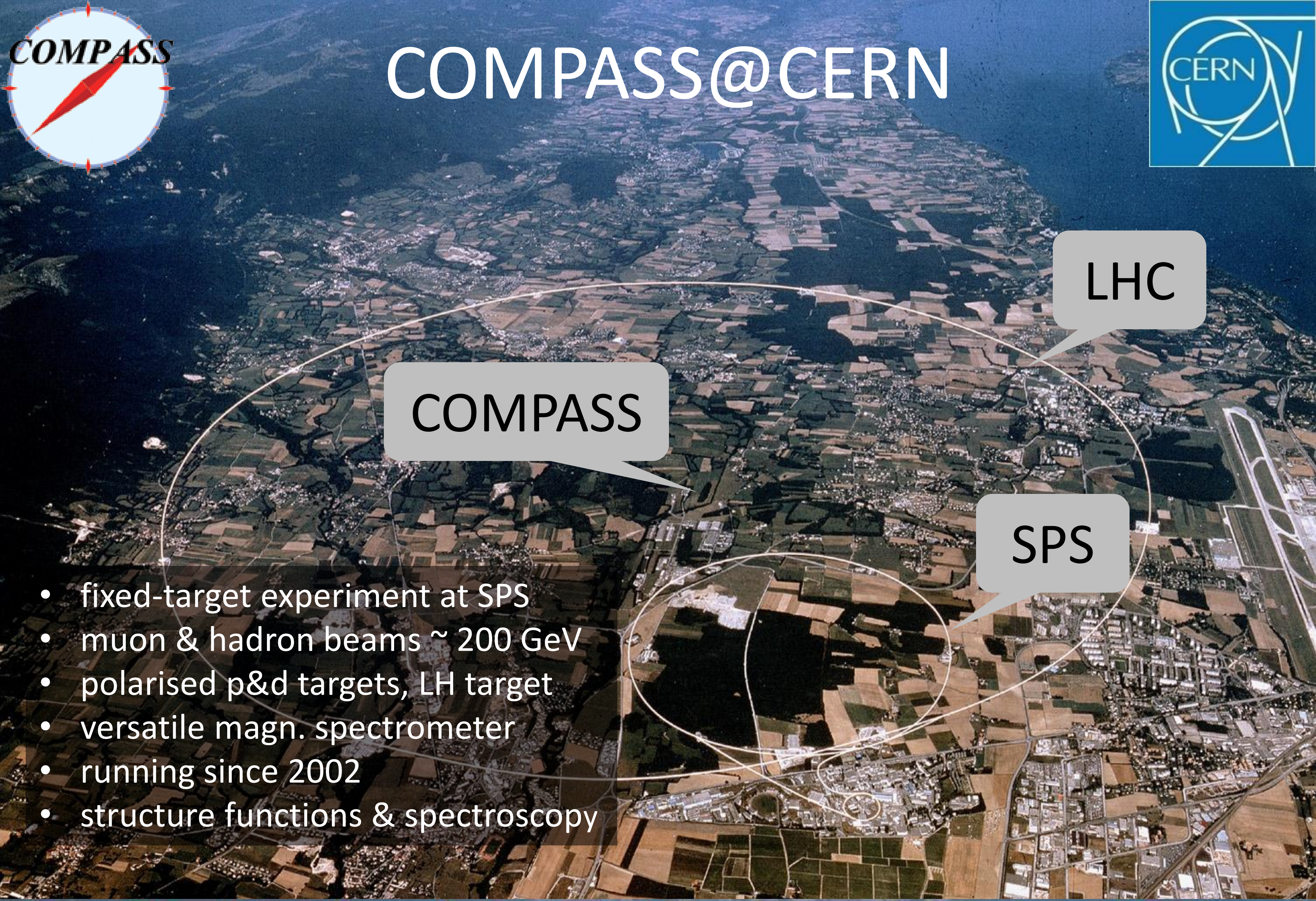
Future Programme of COMPASS at CERN

G. K. Mallot/CERN
on Behalf of the COMPASS Collaboration

COMPASS@CERN



- fixed-target experiment at SPS
- muon & hadron beams ~ 200 GeV
- polarised p&d targets, LH target
- versatile magn. spectrometer
- running since 2002
- structure functions & spectroscopy

COMPASS-II

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN–SPSC–2010–014
SPSC-P-340
May 17, 2010

- Generalized Parton Distributions (GPD)
- Drell-Yan
- Pion (and kaon) Polarizabilities

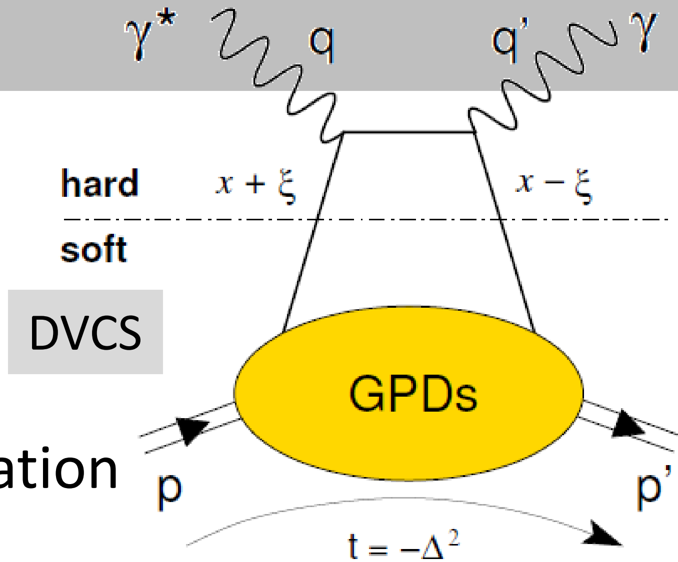
COMPASS-II Proposal

Approved December 2010, first measurements 2012

The COMPASS Collaboration

wwwcompass.cern.ch/compass/proposal/compass-II_proposal/compass-II_proposal.pdf

GPD's



$H(x, \xi, t, Q^2); \quad Q^2$ large, t small

$H^f, E^f, \tilde{H}^f, \tilde{E}^f$ with $f = q, g$

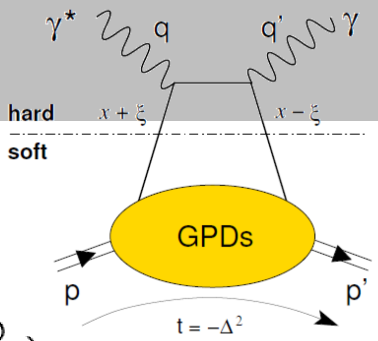
- *H (E)* for nucleon helicity (non)conservation
- PDFs and elastic FF as limiting cases
- $H, \tilde{H} \rightarrow f_1, g_1$ for $\xi \rightarrow 0$; $\quad \int dx\, H(x, \xi, t) = F(t)$
- Correlating transverse spatial and longitudinal momentum DoF
- tools: DVCS, HEMP (vector & pseudoscalar)

Total orbital momentum:

$$J^f(Q^2) = \frac{1}{2} \lim_{t \to 0} \int_{-1}^{1} dx\, x \left[H^f(x, \xi, t, Q^2) + E^f(x, \xi, t, Q^2)\right]$$

X.-D. Ji, PRL 78 (1997) 610

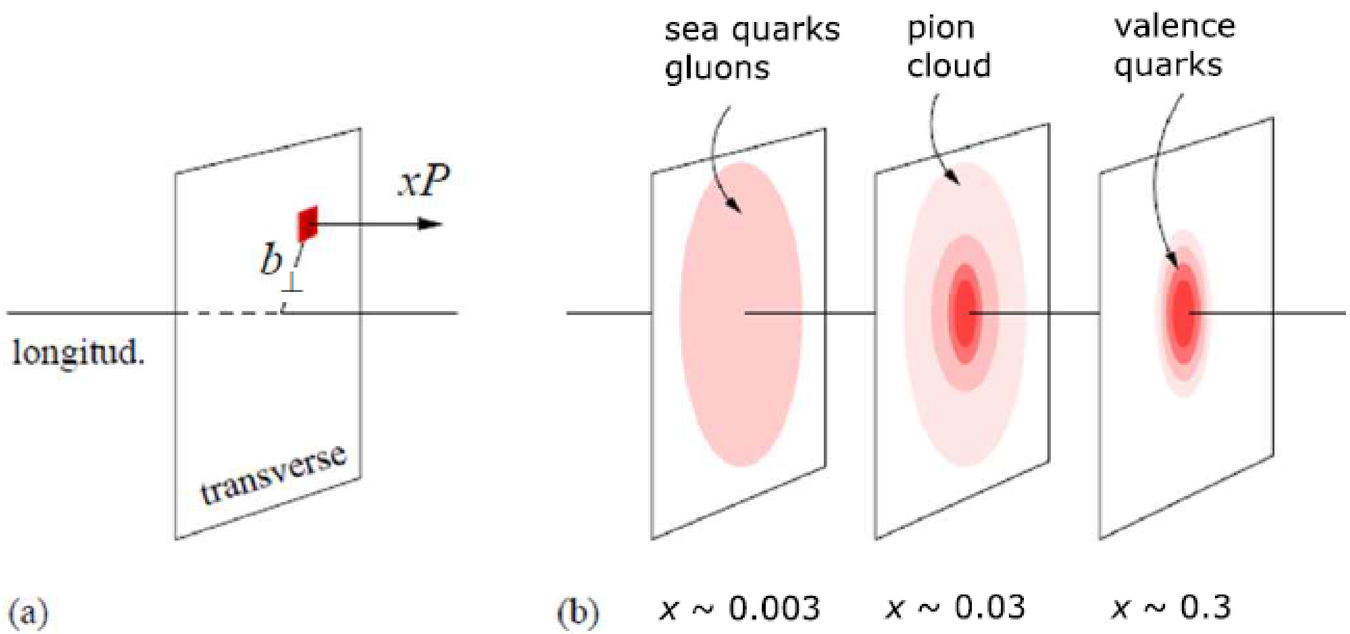
`Tomography'



- ξ=0 → $t = -\Delta_T^{\,2}$, no long. transfer

$$q^f(x, \boldsymbol{b}_\perp) = \int \frac{d^2\boldsymbol{\Delta}_\perp}{(2\pi)^2} \exp(-i\boldsymbol{\Delta}_\perp \cdot \boldsymbol{b}_\perp) H^f(x, 0, -\boldsymbol{\Delta}_\perp^2)$$

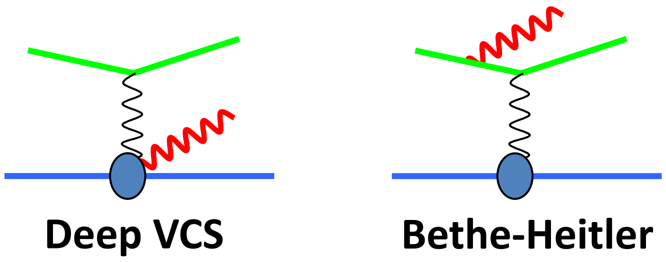
- Transverse size as function of longitudinal momentum fraction



adapted from JLAB 12 GeV CDR

DVCS

- DVCS can be separated from BH and constrain the GPD *H* e.g. using different charge & spin (e_μ & P_μ) cross section combinations of the μ beam
- Note: μ± have opposite polarisation at COMPASS



$$d\sigma^{\mu p\rightarrow \mu p \gamma} = d\sigma^{BH} + d\sigma_0^{DVCS} + P_\mu d\Delta\sigma^{DVCS} + e_\mu \mathrm{Re}\, I + P_\mu e_\mu \mathrm{Im}\, I$$

Charge & Spin difference and sum:

$$\mathcal{S} = d\sigma^{\overset{+}{\leftarrow}} + d\sigma^{\overset{-}{\rightarrow}} = 2(d\sigma^{BH} + d\sigma_0^{DVCS} + \mathrm{Im}\, I)$$

$$\mathcal{D} = d\sigma^{\overset{+}{\leftarrow}} - d\sigma^{\overset{-}{\rightarrow}} = 2(d\sigma_0^{DVCS} + \mathrm{Re}\, I)$$

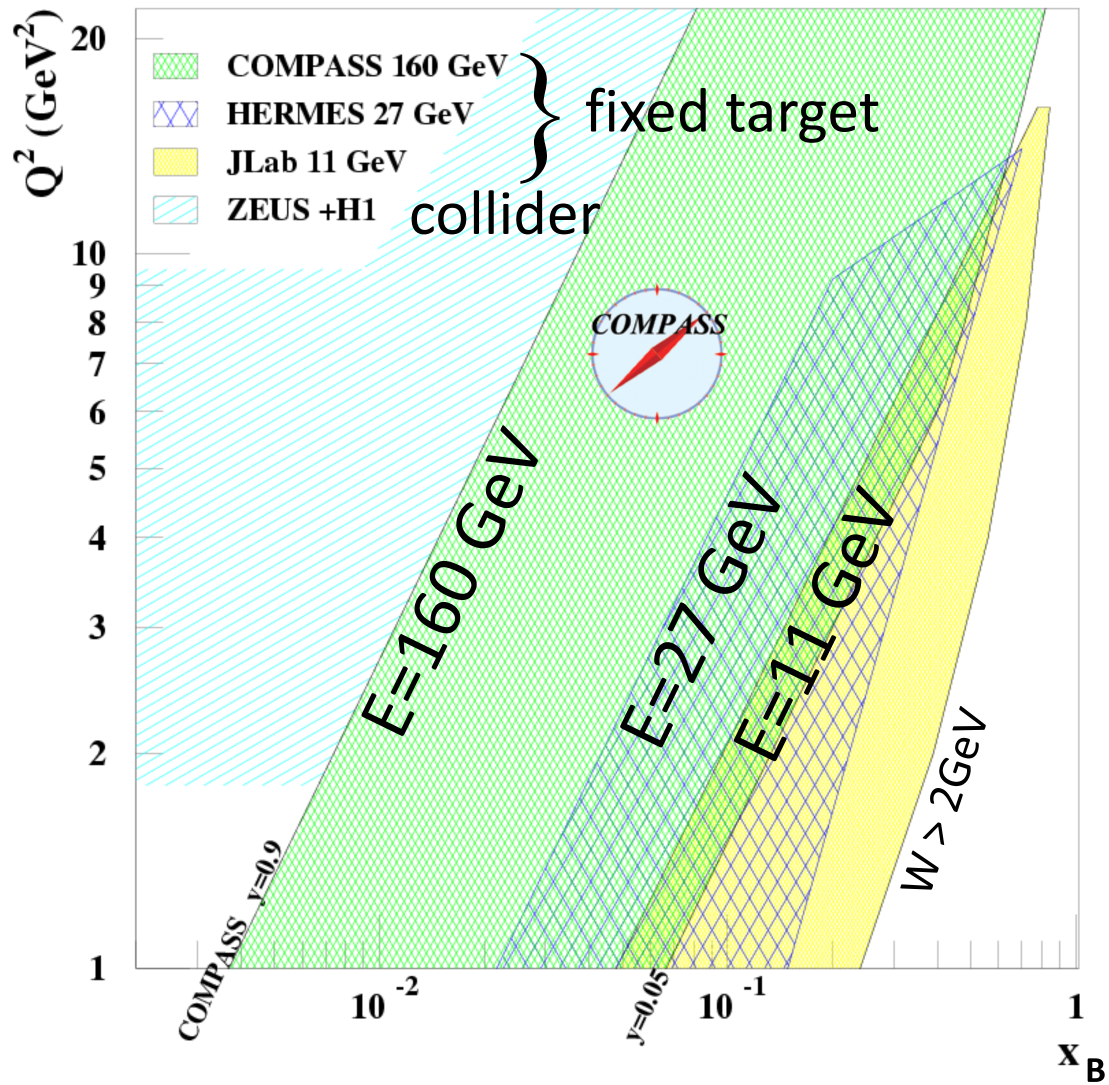
Im and Re related to

$$H(x=\xi, \xi, t)$$

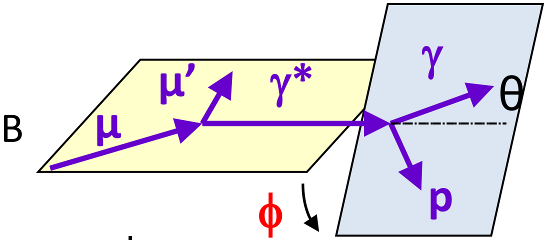
$$\mathcal{P}\int dx\, H(x,\xi,t)/(x-\xi)$$

DVCS

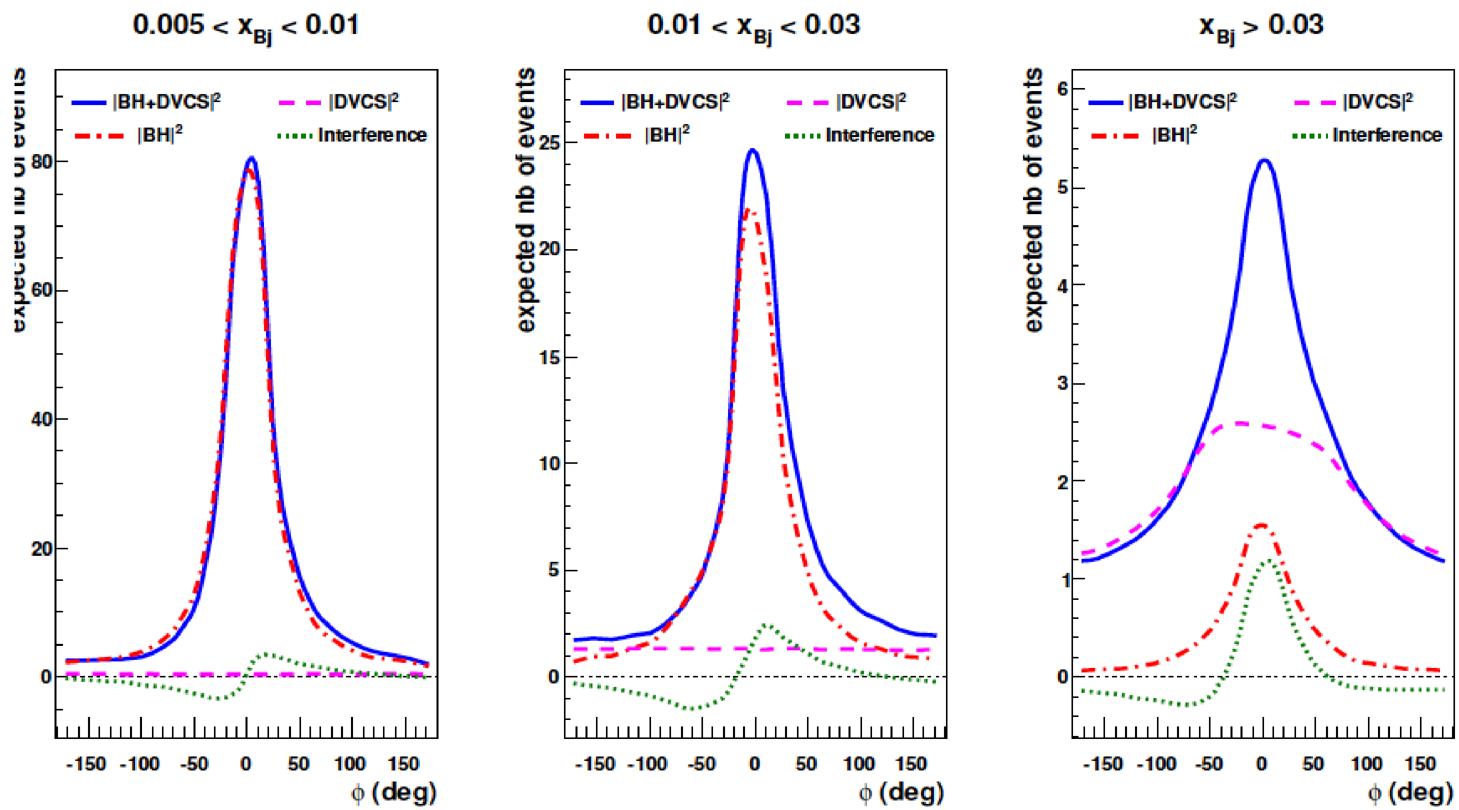
- DVCS is the cleanest process to determine GPDs
- need a world-wide effort
- Global analysis over large kinematic range mandatory
- COMPASS-II: from HERA to JLAB 12 GeV kinematics



BH vs DVCS simulation

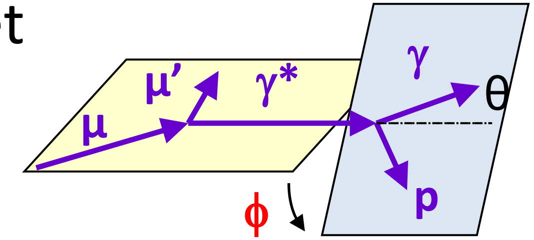


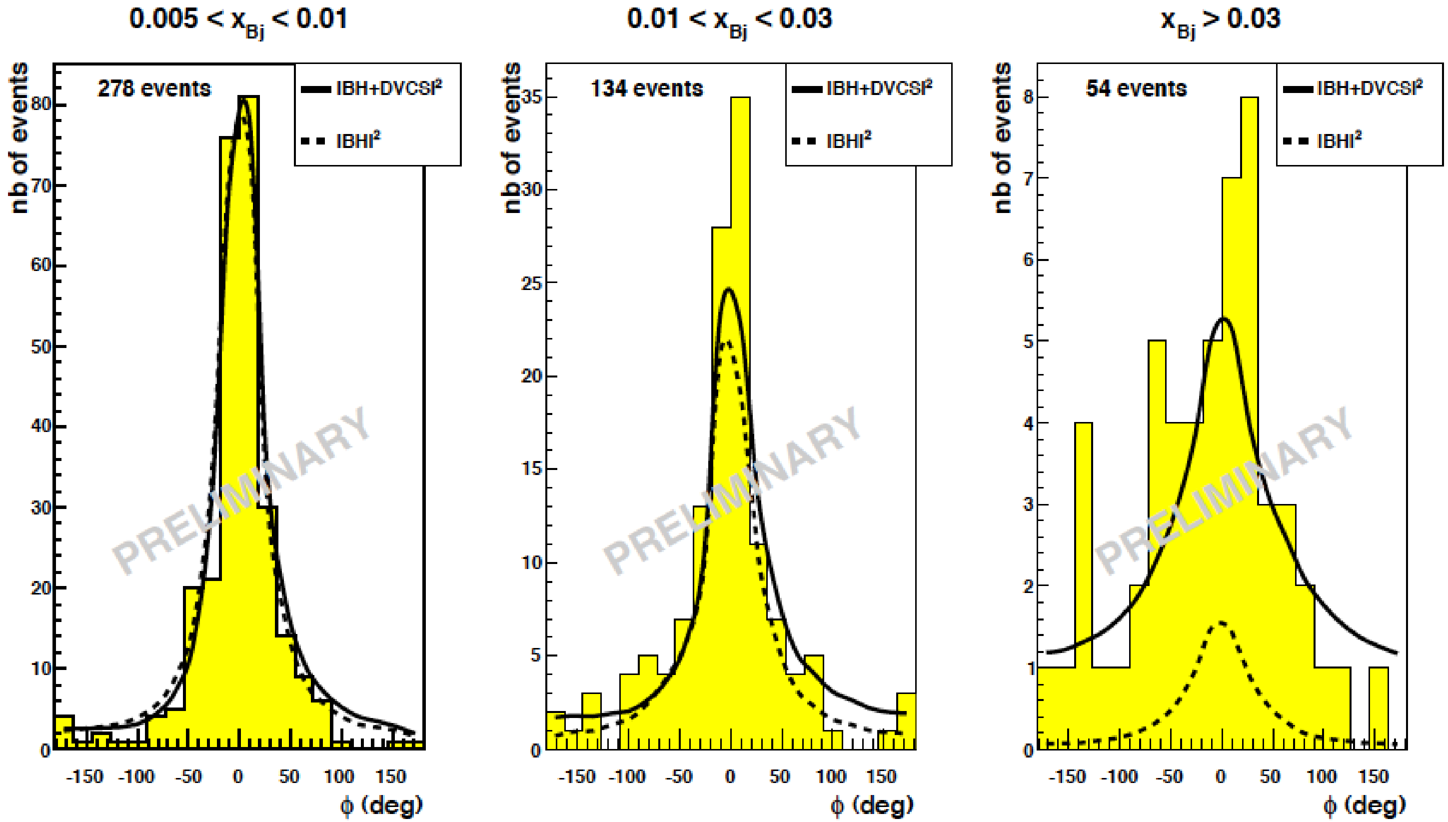
- Rapid variation of relative contributions with x_B
- Normalisation of BH contribution at small x_B
- Interference term vanishes upon integration over ϕ



BH vs DVCS data

- Test runs in 2008/2009 – 40 cm long LH target
- Clear DVCS signal, BH (- - - -) can subtracted





transverse proton size

- The distance $\langle r_\perp{}^2 \rangle$ between struck quark and spectator c.m. given by *t*-slope of DVCS cross-section σ_0 (as function of x_{Bj}, LO)

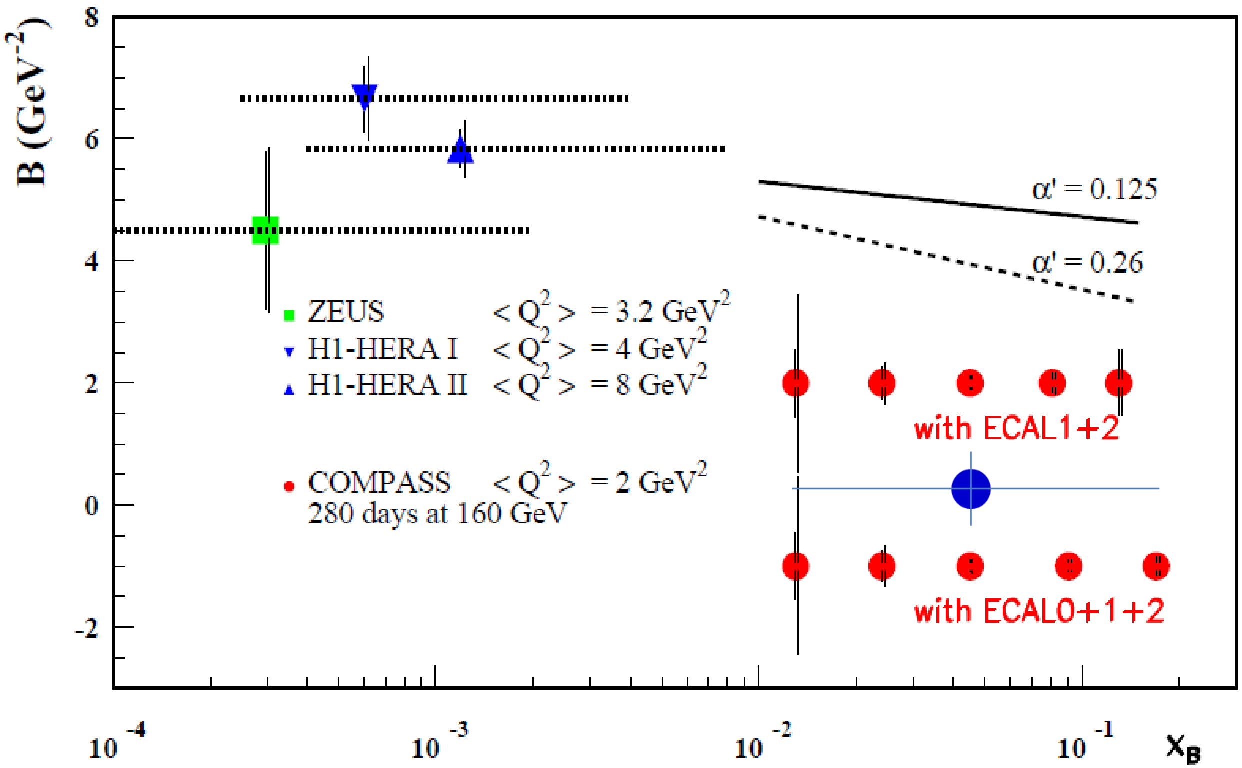
$$\frac{d\sigma_0^{DVCS}}{dt} \propto \exp(-B(x_B)|t|) \qquad \langle r_\perp^2(x_B)\rangle \approx 2B(x_B)$$

- Reminder $\mathcal{S} = 2(d\sigma^{BH} + d\sigma_0^{DVCS} + \mathrm{Im}\, I)$
- Subtract BH from $\mathcal{S}$, integrate over $\phi \rightarrow \sigma_0$
- H1 found 0.65 ± 0.02 fm at $x_{Bj} \approx 10^{-3}$

- Parametrisation $B(x_B) = B_0 + 2\alpha' \log \frac{x_0}{x_B}$

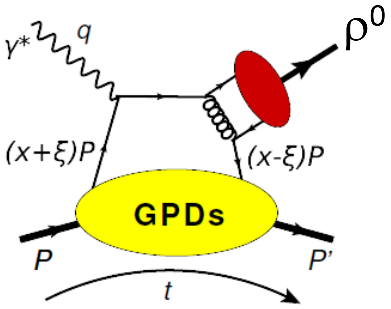
projected t-slope

- COMPASS-II projection, 2 years of data taking ● , pilot run 2012 ●
- x_B region unique to COMPASS
- transition from HERA → HERMES/JLab



$$B(x_B) = B_0 + 2\alpha' \log \frac{x_0}{x_B}$$

t-slope for ρ^0 production

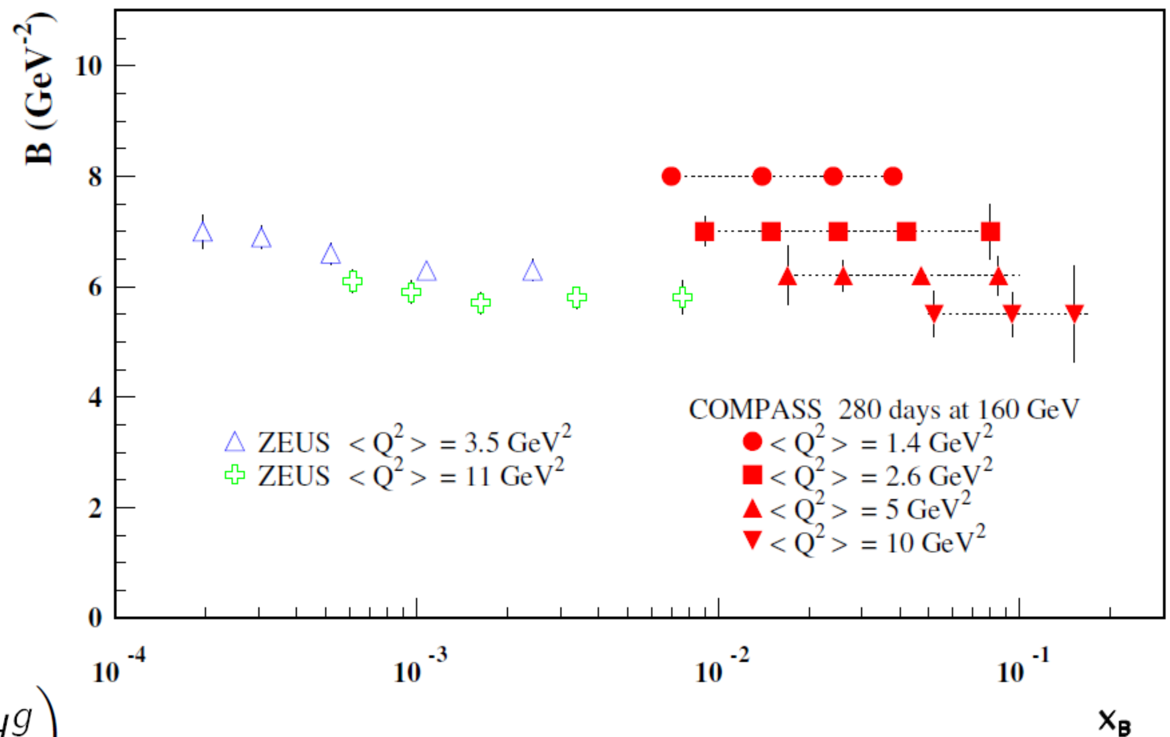


also ϕ, ω, ..

$$H_{\rho^0} = \frac{1}{\sqrt{2}}\left(\frac{2}{3}H^u + \frac{1}{3}H^d + \frac{3}{8}H^g\right)$$

$$H_{\omega} = \frac{1}{\sqrt{2}}\left(\frac{2}{3}H^u - \frac{1}{3}H^d + \frac{1}{8}H^g\right)$$

$$H_{\phi} = -\frac{1}{3}H^s - \frac{1}{8}H^g$$

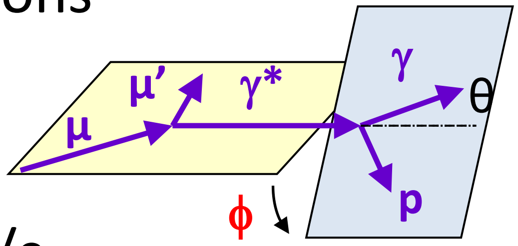


Wollny, Wed 15:15

COMPASS II proj. data

$$\mathcal{A} = \frac{d\sigma^{\overset{+}{\leftarrow}} - d\sigma^{\overset{-}{\rightarrow}}}{d\sigma^{\overset{+}{\leftarrow}} + d\sigma^{\overset{-}{\rightarrow}}} = \frac{\mathcal{D}}{\mathcal{S}}$$

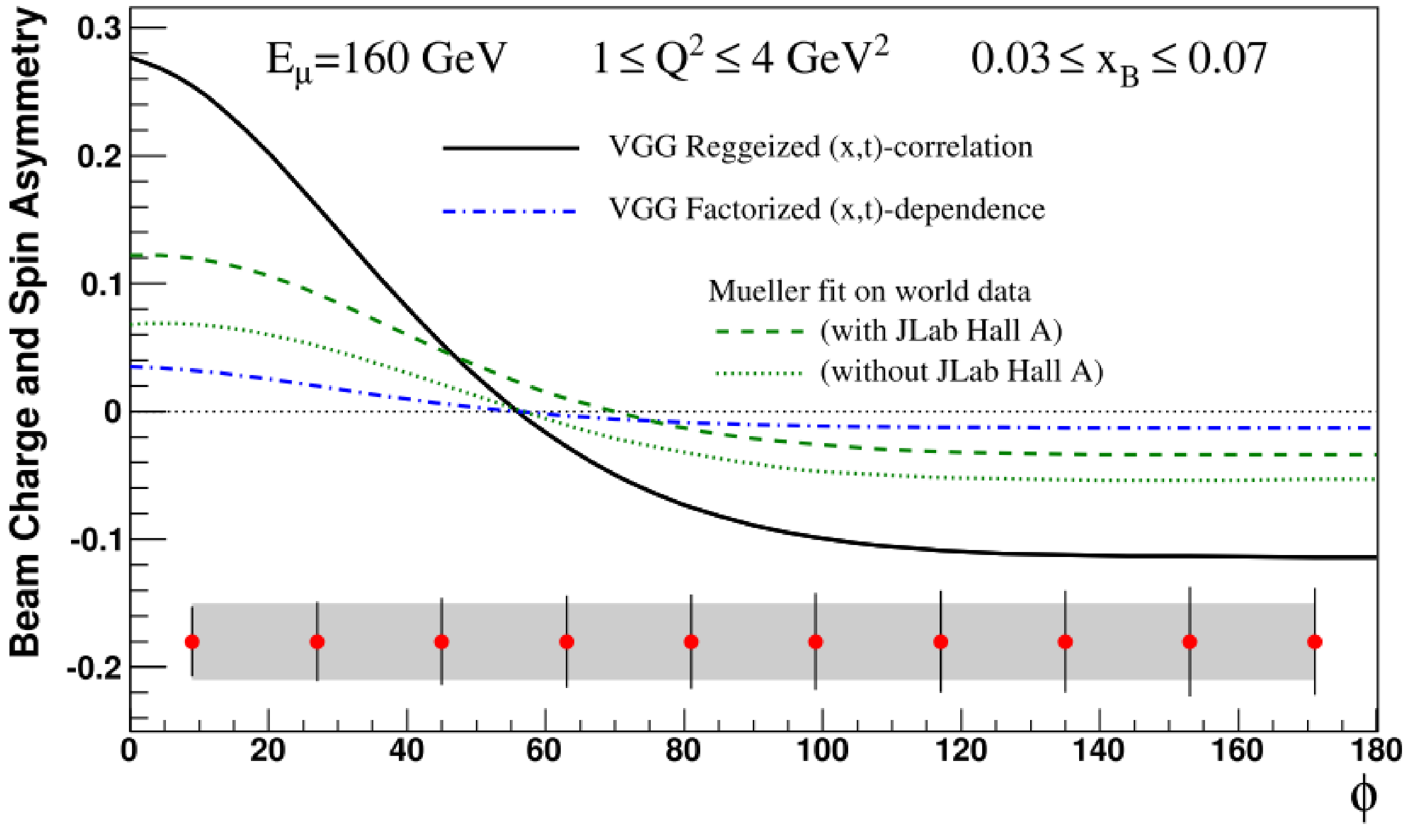
- Example: Charge & spin asymmetry
- Cancelation of several experimental uncertainties
- Easier to measure than absolute cross-sections
- Asymmetries, sums and differences in $6x_B \times 4\ Q^2$ bins as function of ϕ
- Simulation for 2 years data taking, 160 GeV/c and a 2.5 m long liquid H_2 target
- LO:



$$\mathcal{S} : \mathrm{Im}\, I, \quad \sin\phi \text{ dependence}, \quad H(x=\xi,\xi,t)$$

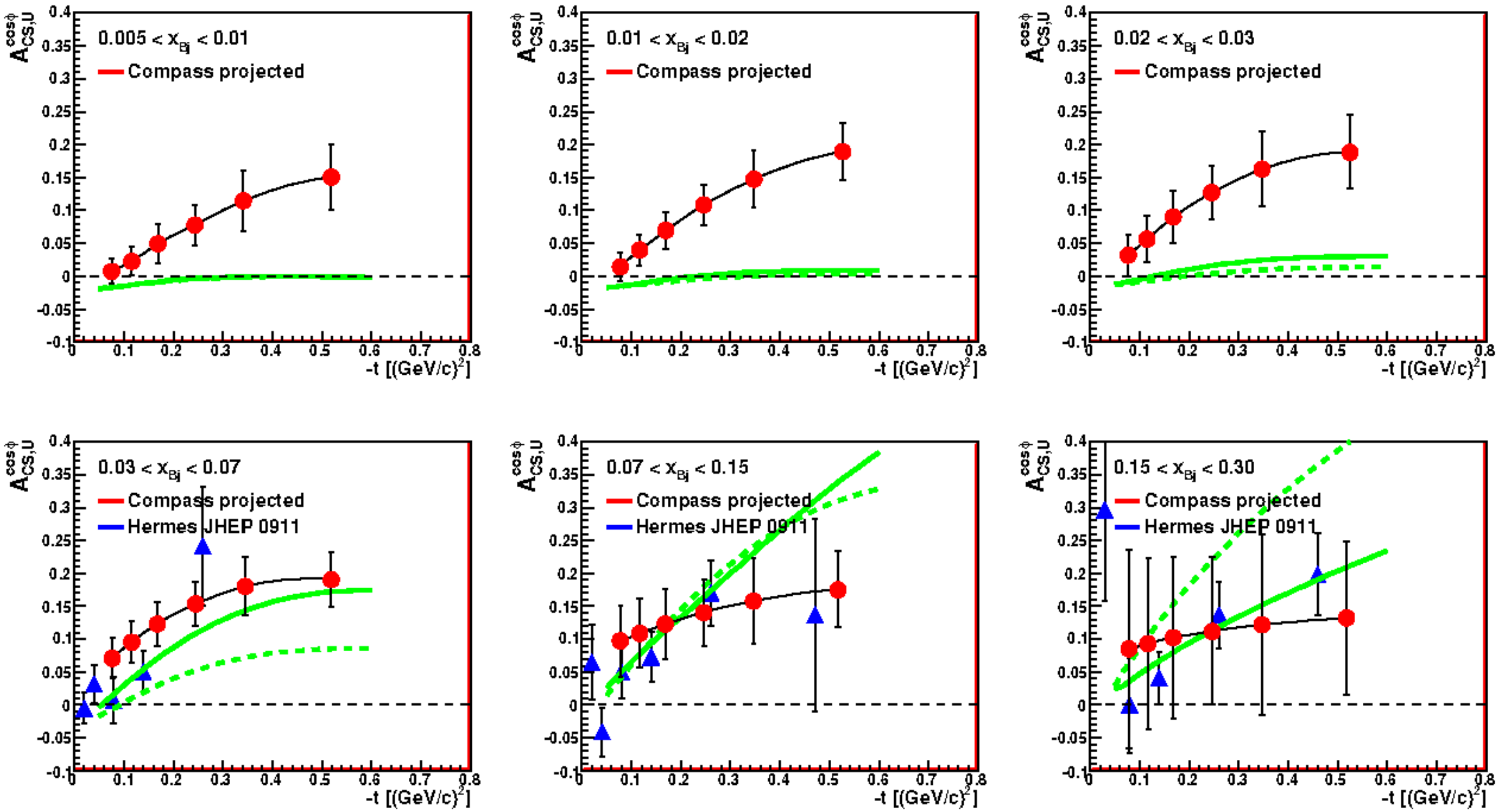
$$\mathcal{D} : \mathrm{Re}\, I, \quad \cos\phi \text{ dependence}, \quad \mathcal{P}\int dx\, H(x,\xi,t)/(x-\xi)$$

Proj. charge & spin asymmetry



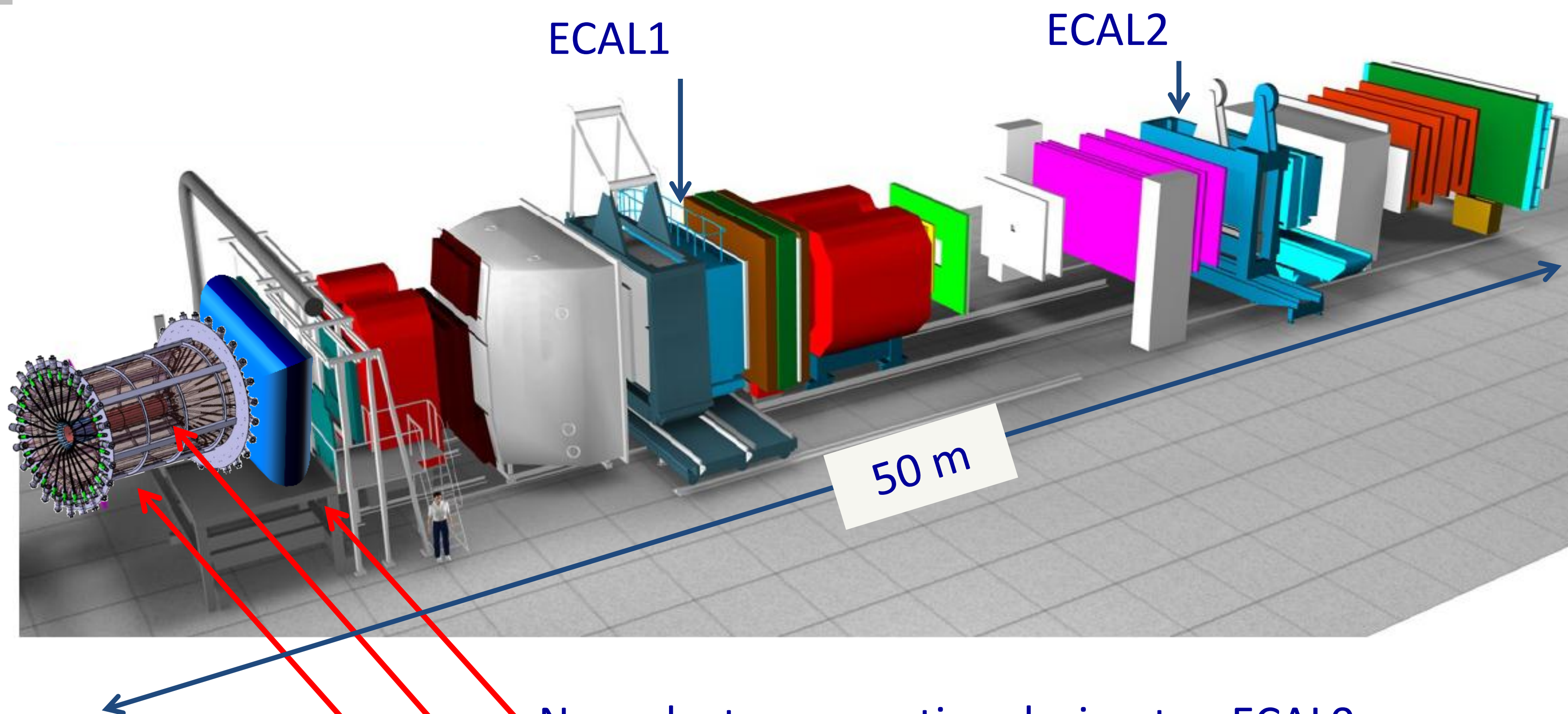
Beam charge-and-spin asym.

amplitude of cos ϕ modulation as fctn of -*t*



fits by Kumericki, Mueller

DVCS – main new equipment

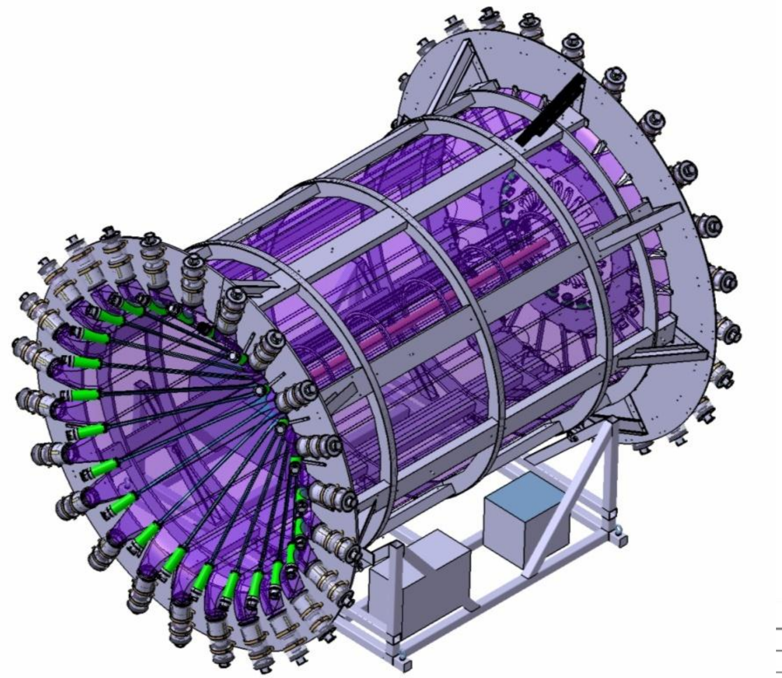


New electromagnetic calorimeter, ECAL0

Liquid hydrogen target, 2.5 m long

Proton Time-Of-Flight detector, 4.0 m long

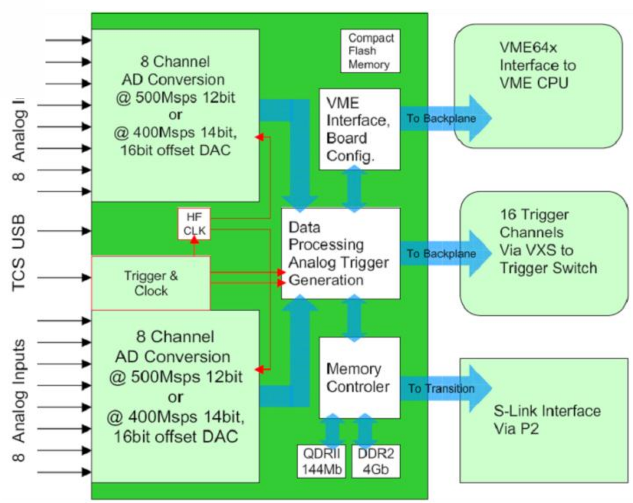
Experimental setup: Camera

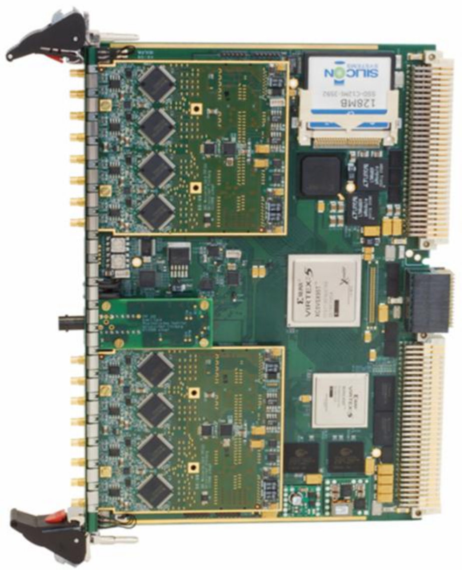


- 2 barrels 4m long long scintillators
- ~ 300 ps timing resolution
- 2.5 m long LH2 target

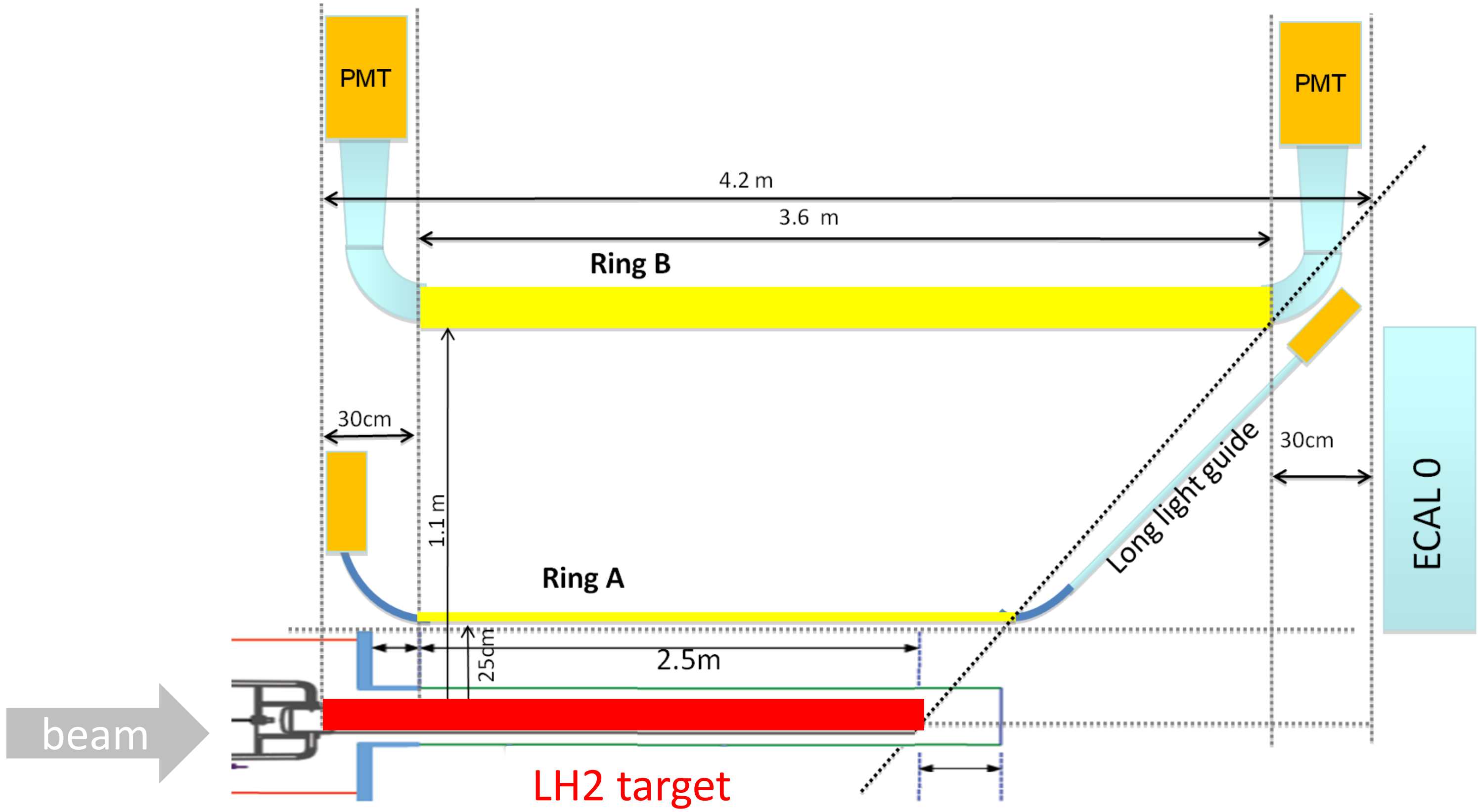
Gandalf Readout Project:

1 GHz digitalisation of the PMT signal to cope for high rate





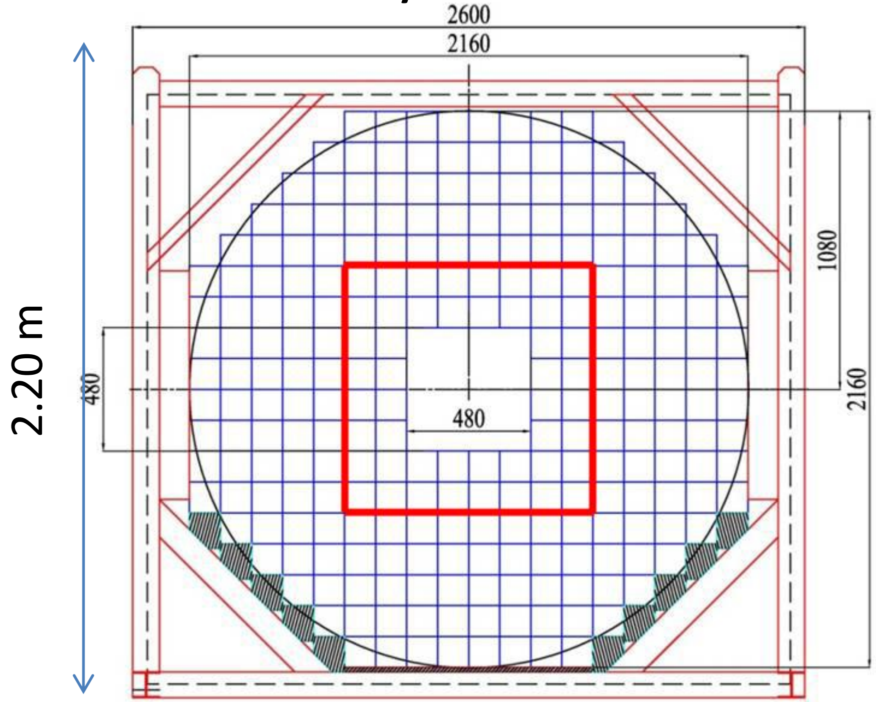
Geometry target region



ECAL0

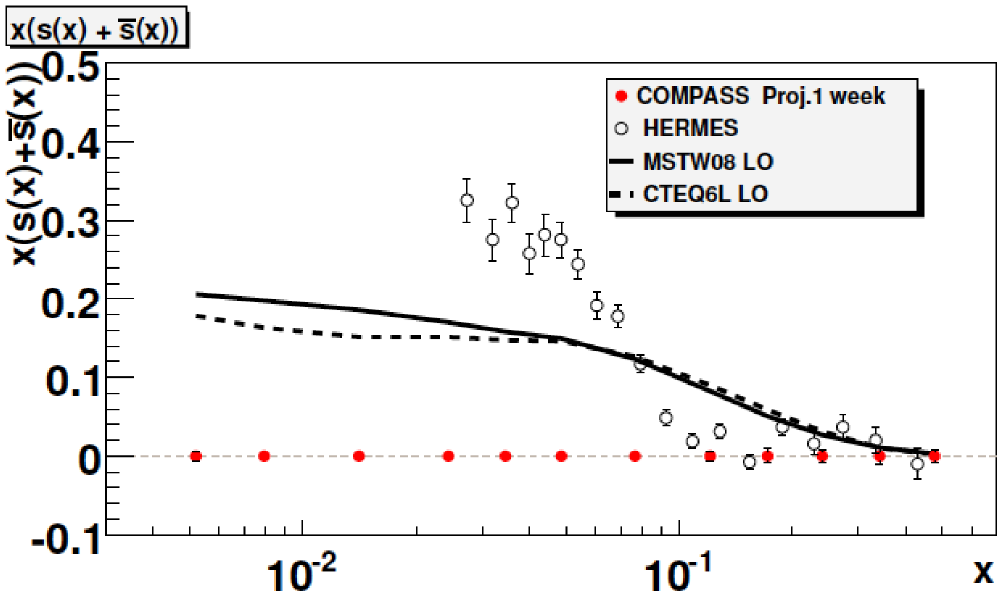
- new **ECAL0** large angle calorimeter
- Multipixel Avalanche Photodiode readout

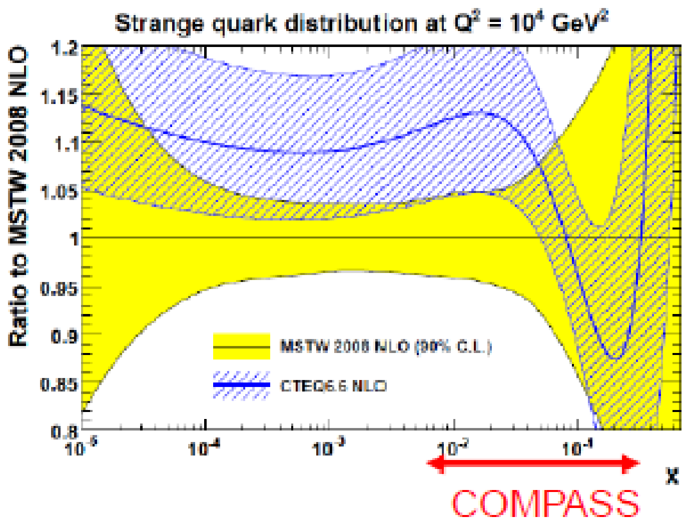
ECAL0 248 modules (12 × 12 cm²) of 9 cells read by 9 MAPDs



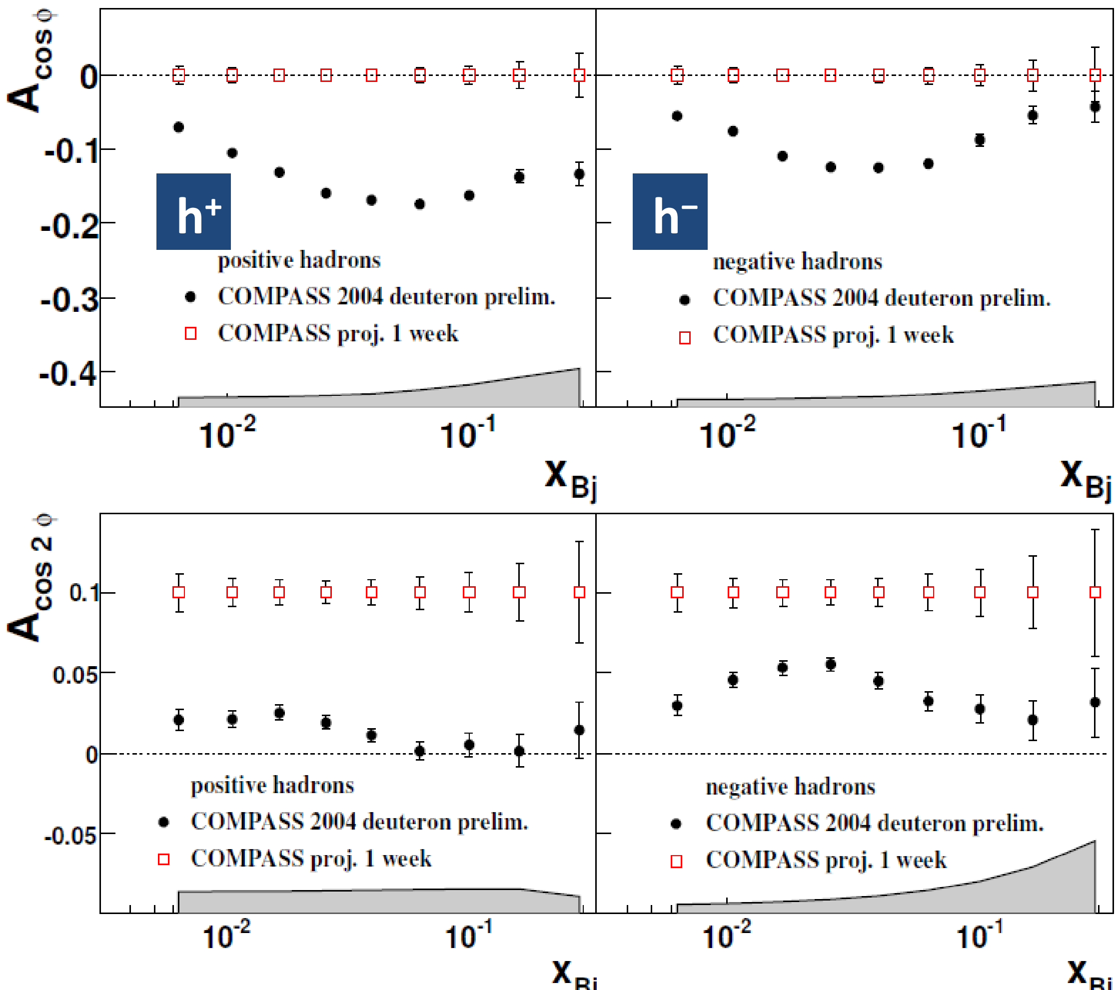
Semi-inclusive DIS

- COMPASS I had ^{6}LiD and NH_3 (i.e. deuterons for unpol.)
- COMPASS II pure hydrogen target in parallel with DVCS
  - Hadron multiplicities for FF, strange quark PDF
  - spin-averaged azimuthal proton asymmetries





Azimuthal unpol. Asym.

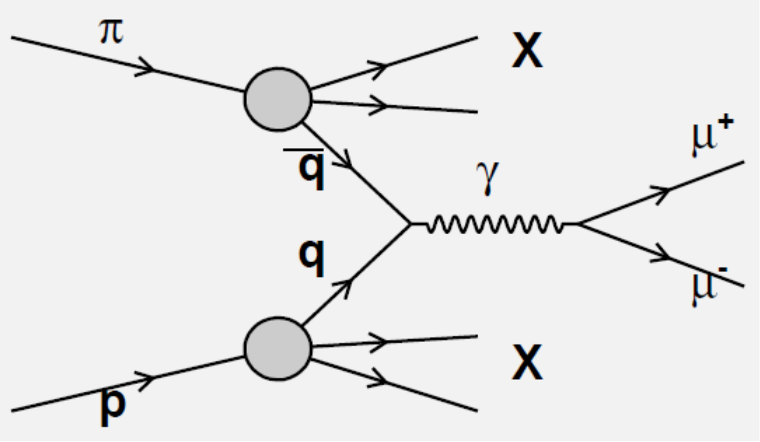


Cahn

Boer-Mulders

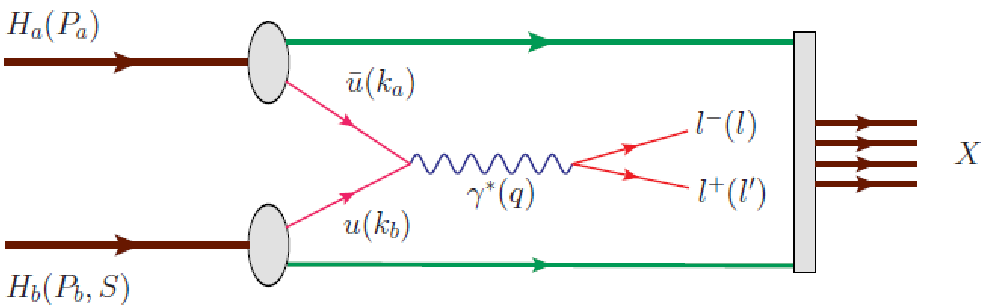
Drell–Yan Process

- No fragmentation function involved
- Convolution of two PDFs
- Best: pol. antiproton–proton (long-term)
- Simpler: negative pion on pol. proton (short-term)
- Pion valence anti-u annihilates with proton u

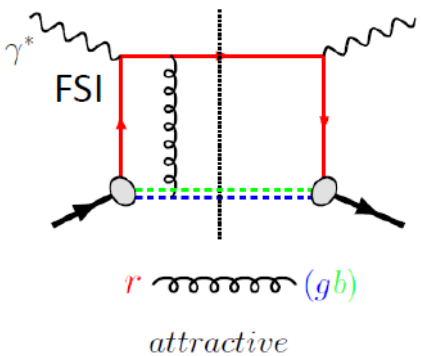


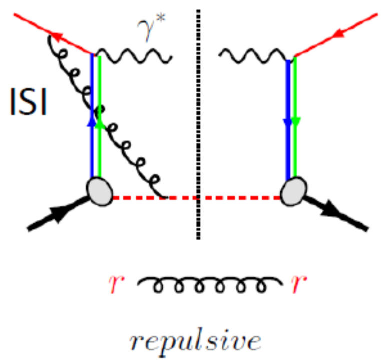
$$\sigma^{DY} \propto f_{\overline{u}|\pi^-} \otimes f'_{u|p}$$

Restricted universality in SIDIS and DY



T-odd TMD





`gauge link changes sign for T-odd TMD', restricted universality of T-odd TMDs

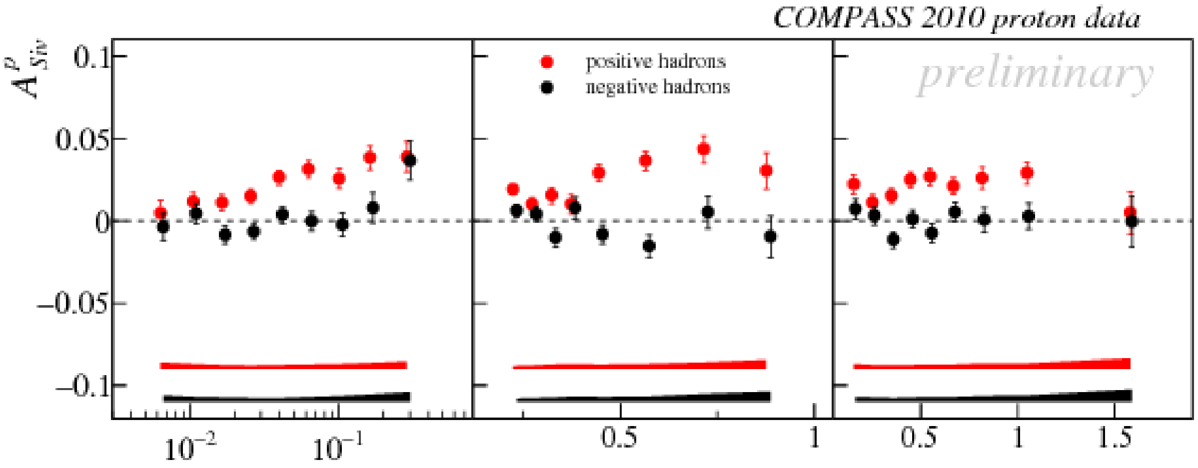
J.C. Collins, PLB536 (2002) 43

$$f_{1T}^{\perp}\Big|_{DY} = -f_{1T}^{\perp}\Big|_{DIS} \quad \text{and} \quad h_1^{\perp}\Big|_{DY} = -h_1^{\perp}\Big|_{DIS}$$

Sivers

Boer-Mulders

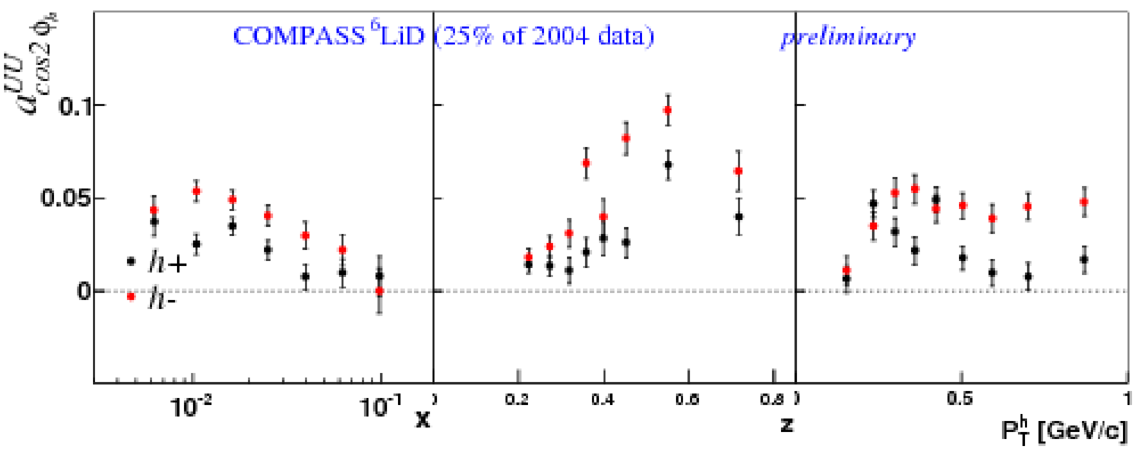
DIS: Sivers & BM



Sivers

Proton

Ch. Adolph
today 11:35



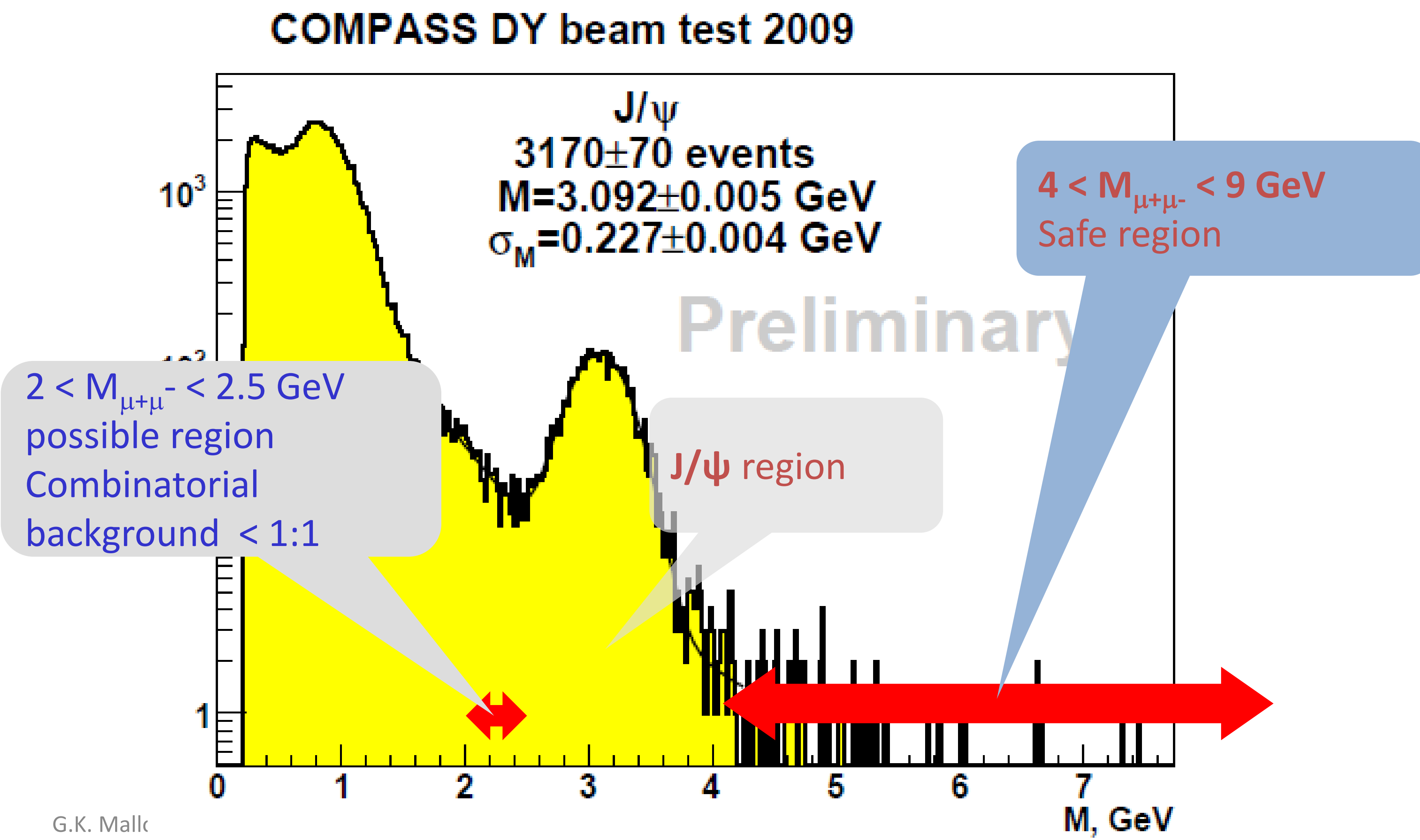
Boer-Mulders

Deuteron

Future DY experiments

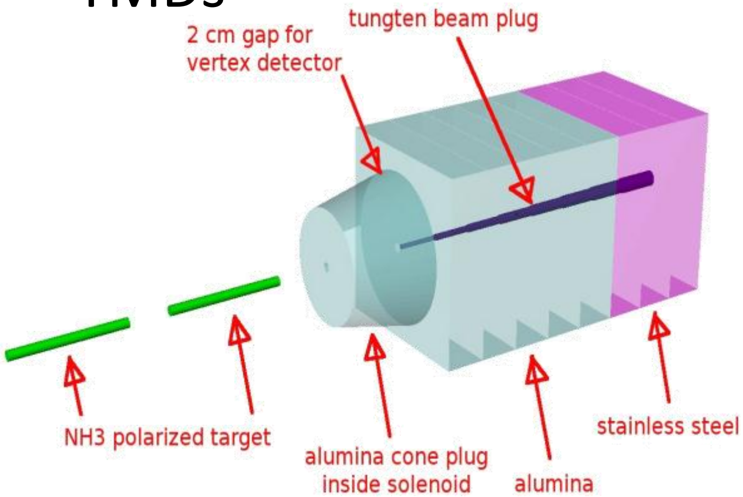
Facility	Type		s (GeV^2)	Time-line
RHIC (STAR, PHENIX)	collider,	$p^\Uparrow p^\Uparrow$	200^2, 500^2	> 2015
RHIC(internal target)	fixed target,	$p^\Uparrow p^\Uparrow$	500	> 2016
RHIC(AnDY)	collider,	$p^\Uparrow p^\Uparrow$	500^2	> 2013
JPARC	fixed target,	$pp^\Uparrow$	$60 \div 100$	> 2017
GSI(PAX)	collider,	$\overline{p}^\Uparrow p^\Uparrow$	200	> 2020
GSI (Panda)	fixed target,	$\overline{p}p$	30	> 2017
NICA	collider,	$p^\Uparrow p^\Uparrow$, $d^\Uparrow d^\Uparrow$	676	> 2017
COMPASS	fixed target,	$\pi^- p^\Uparrow$	$300 \div 400$	2014

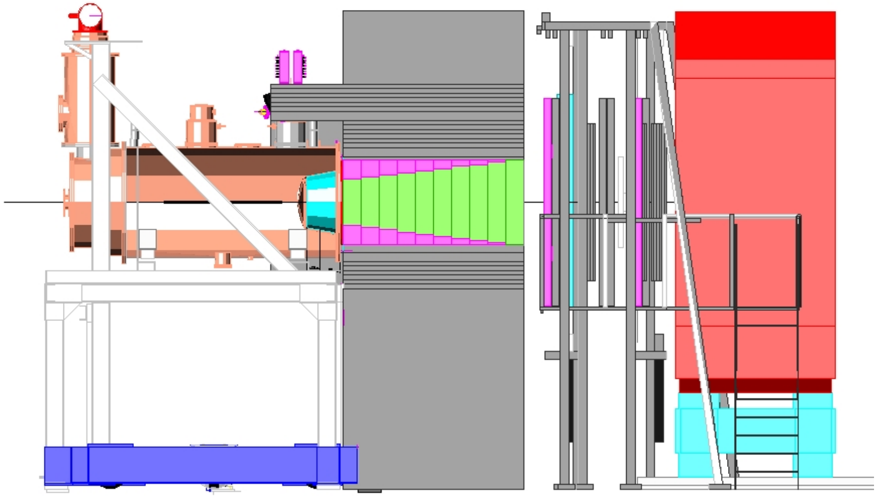
Drell–Yan muon pair mass regions



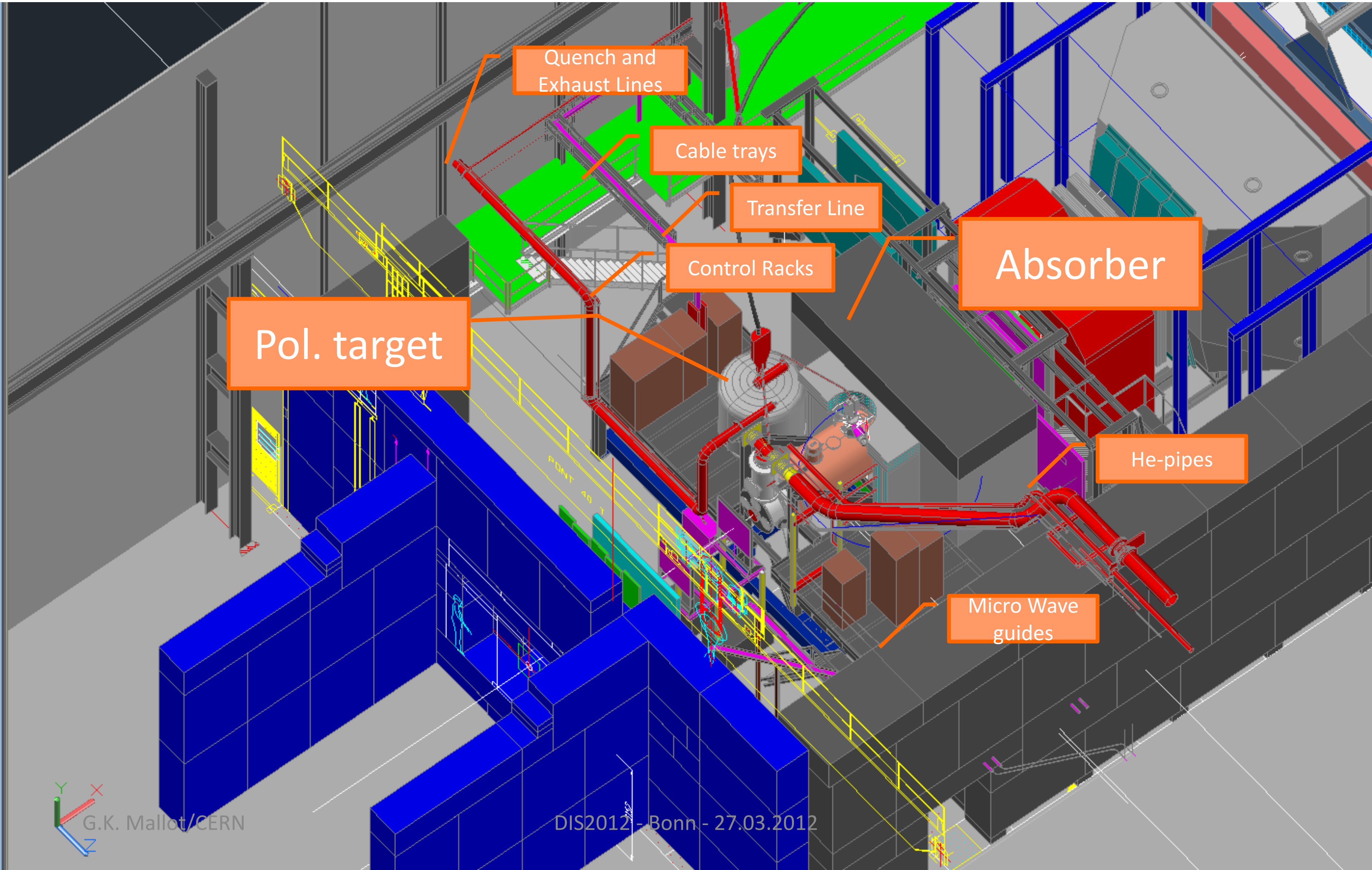
COMPASS-II Polarised Drell-Yan

- COMPASS-II: 190 GeV/c π^- beam on transversely pol. proton target
- π^- valence u-antiquark picks nucleon's u quark in valence region (u-quark dominance)
- Access to transversity , the T-odd Sivers and Boer-Mulders TMDs



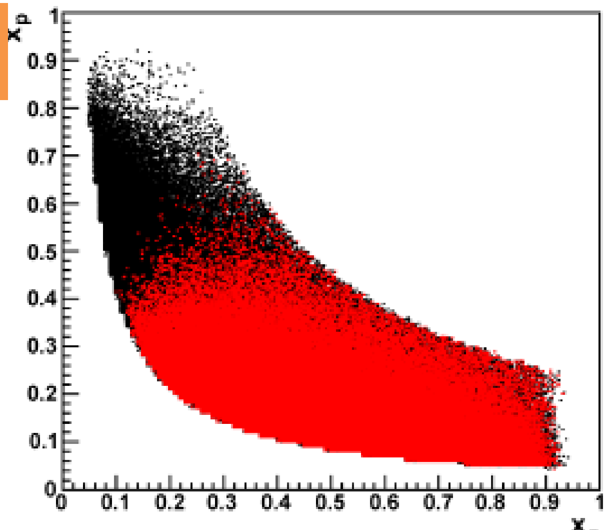


Target region for DY

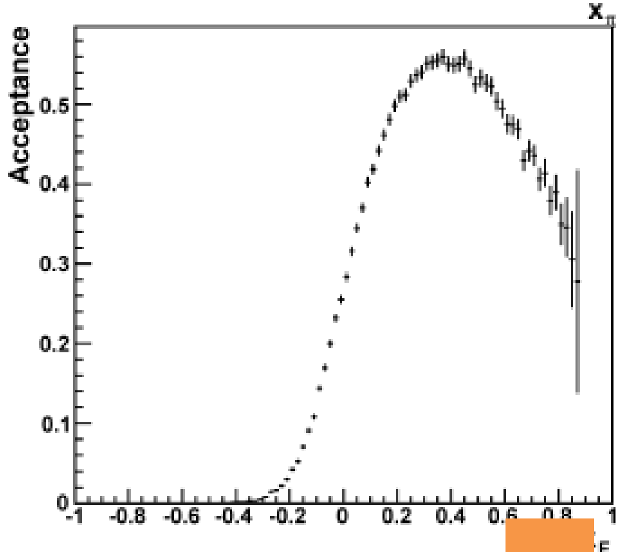


COMPASS polarized DY

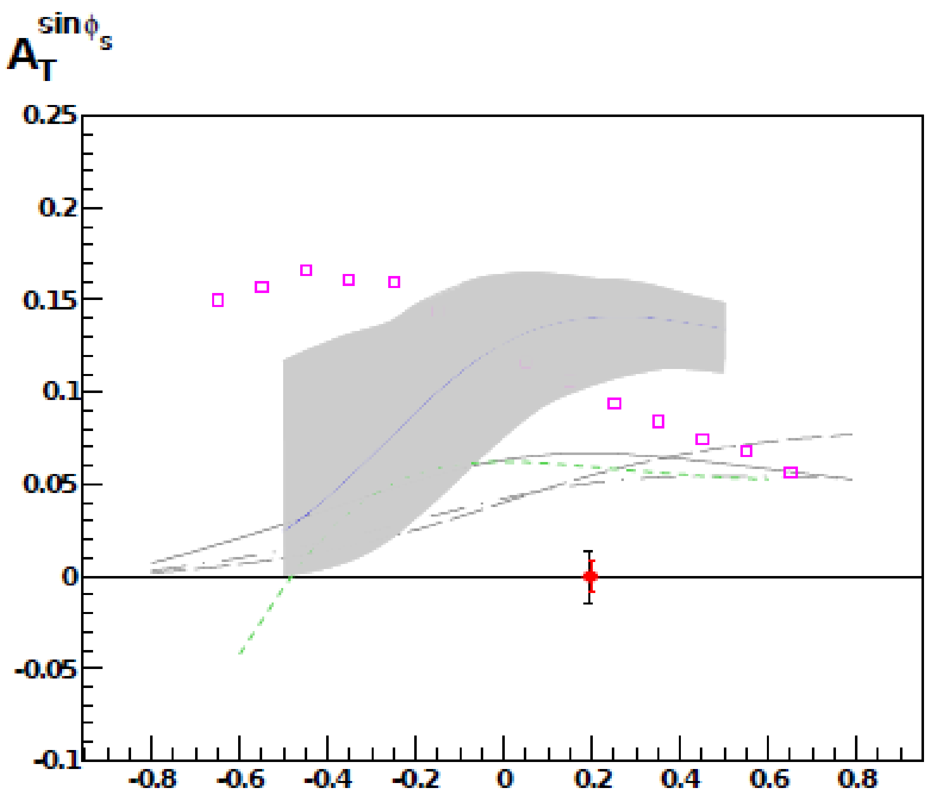
x_p



x_π



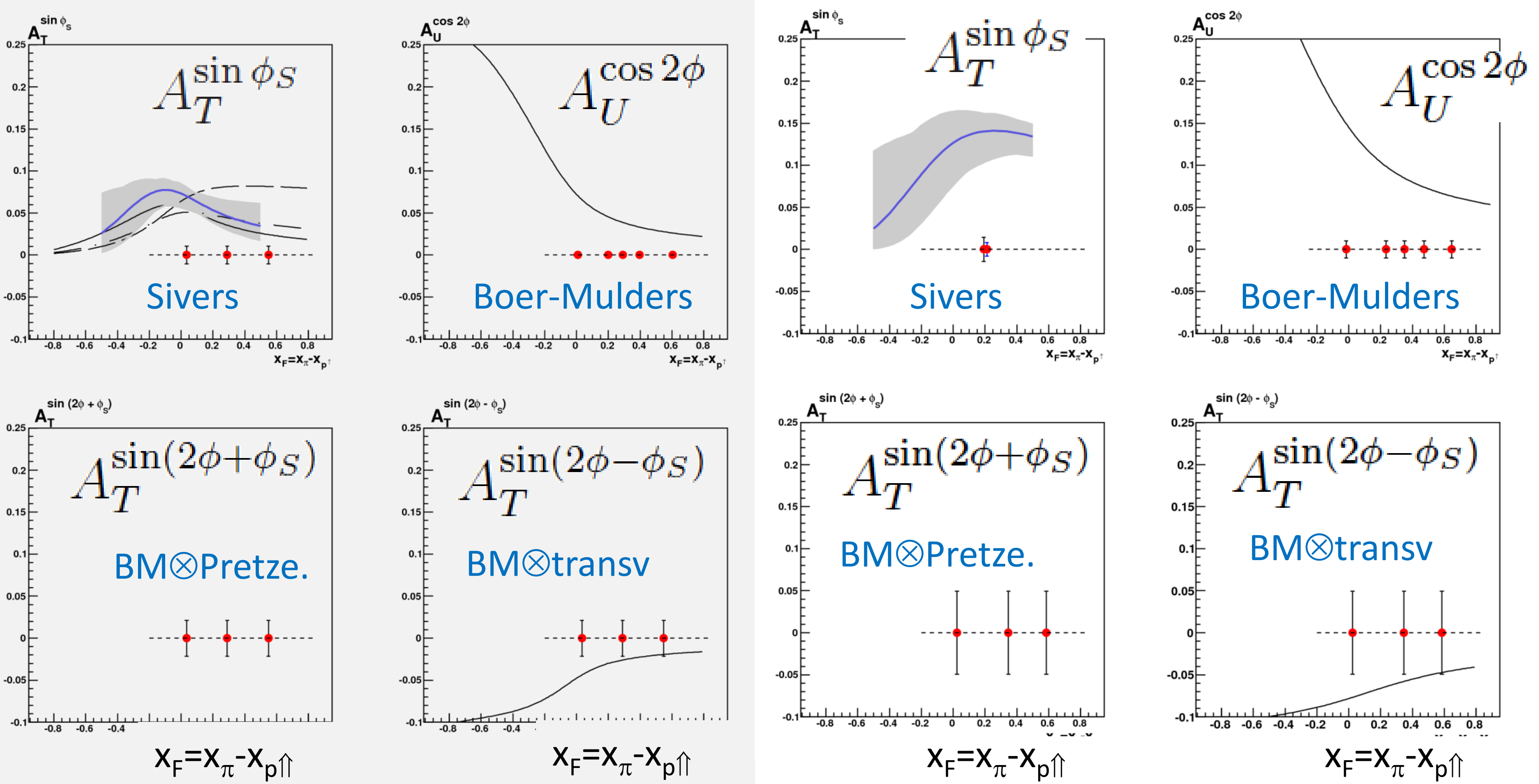
x_F



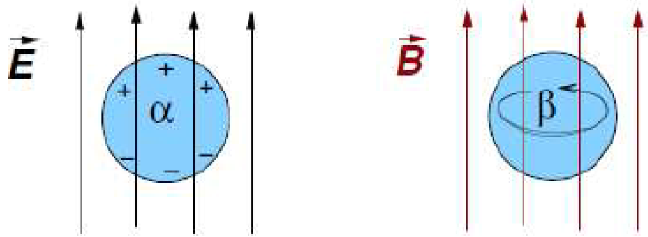
$x_F = x_\pi - x_p$

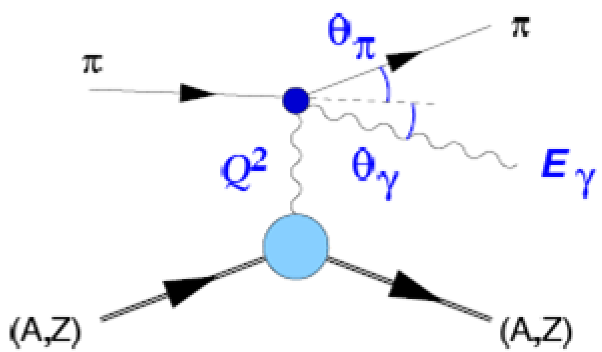
More projections

$2.0 \leq M_{\mu\mu} \leq 2.5\ \mathrm{GeV/c^2}$ | $4. \leq M_{\mu\mu} \leq 9.\ \mathrm{GeV/c^2}$



Tests of χ PT





- Pion (and kaon) polarisability via Primakoff scattering
- control measurement with muons
- present exp. situation confused

	$\alpha_\pi - \beta_\pi$ $(10^{-4}\ \mathrm{fm}^3)$	$\alpha_\pi + \beta_\pi$ $(10^{-4}\ \mathrm{fm}^3)$	$\alpha_2 - \beta_2$ $(10^{-4}\ \mathrm{fm}^3)$
2-loop ChPT prediction	5.7 ± 1.0	0.16 ± 0.10	16
COMPASS sensitivity	± 0.66	± 0.025	± 1.94

COMPASS-II schedule

2012 Primakoff scattering:	Polarizabilities of π and K
DVCS pilot run:	*t*-slope, transverse size
2013 Accelerator shutdown	
2014 Drell-Yan :	Universality of TMDs
2015–2016 DVCS and DVMP:	Study GPDs, “nucleon tomography”
Unpolarized SIDIS:	FF, strangeness PDF, TMDs

... DVCS and HEMP with transversely polarised target

... further spectroscopy measurements