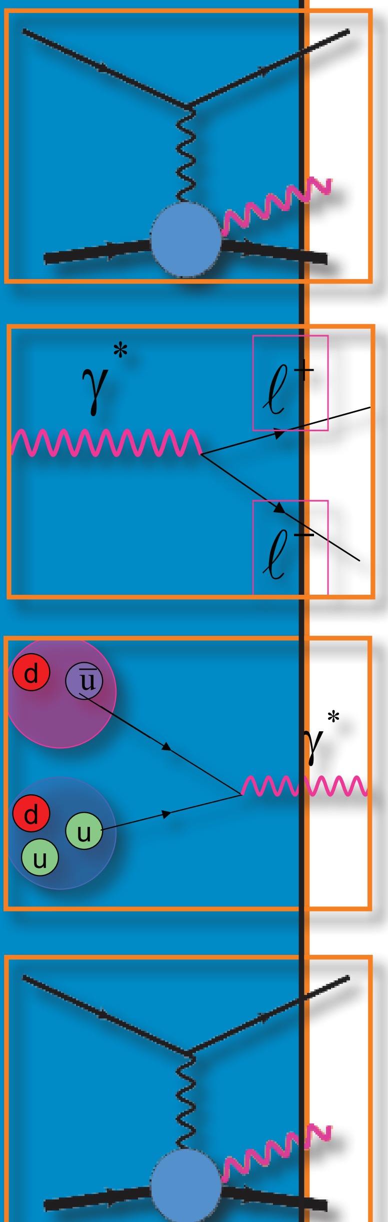
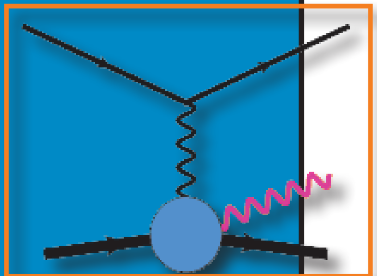


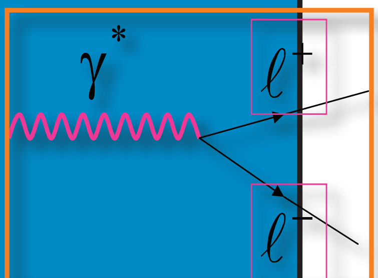
COMPASS - II

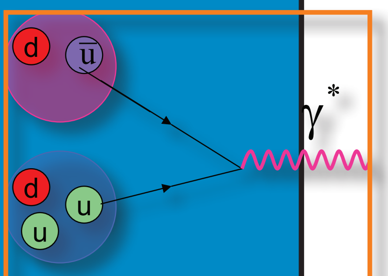
M. Chiosso, University of Torino and INFN
on behalf of the COMPASS Collaboration

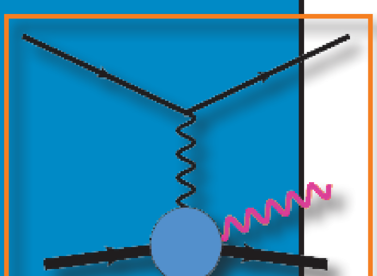
Spin2012 - Dubna (Russia)
17 - 22 September 2012

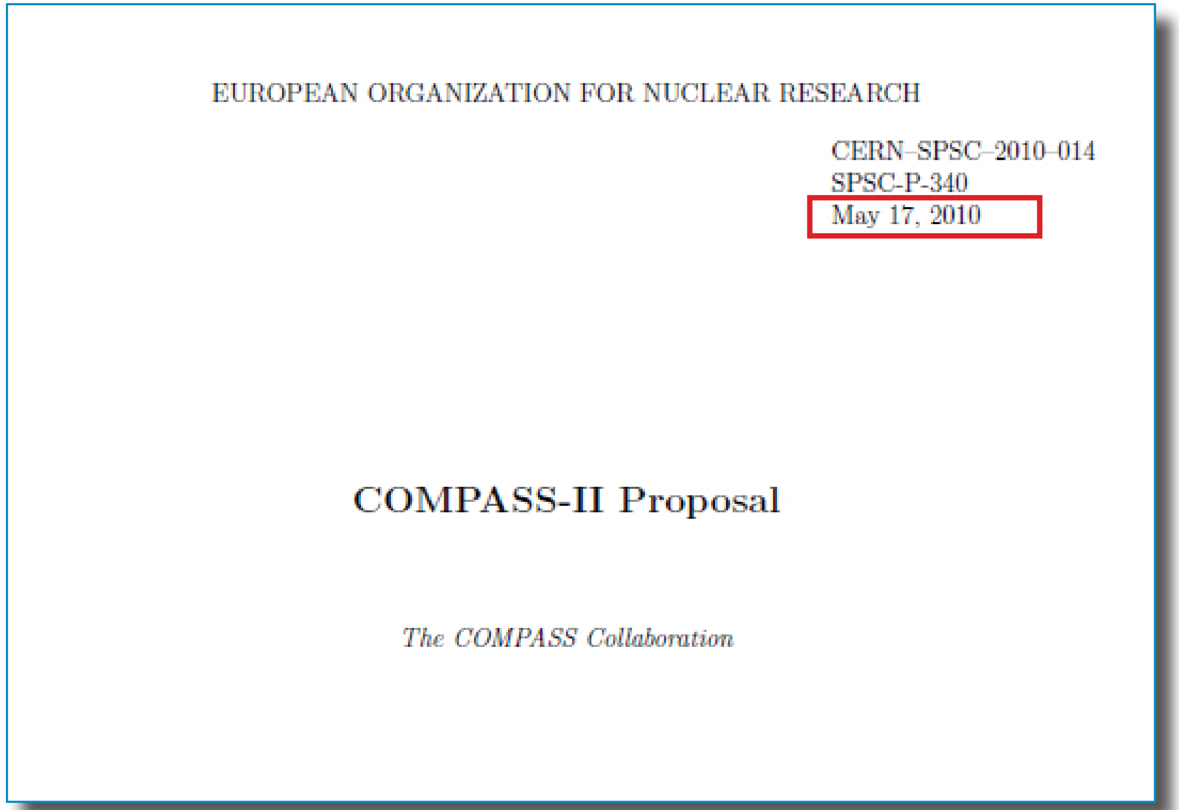
COMPASS-II Proposal











EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

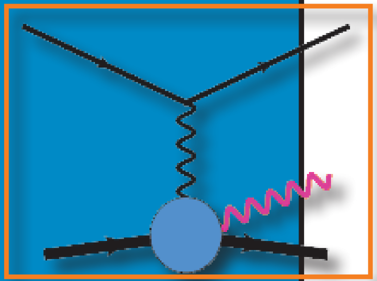
CERN–SPSC–2010–014
SPSC-P-340
May 17, 2010

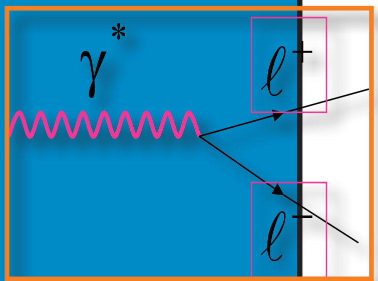
COMPASS-II Proposal

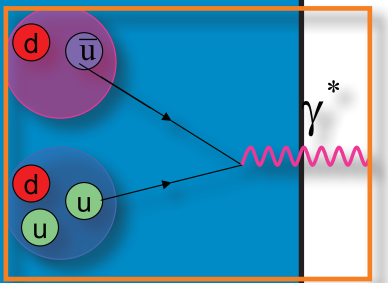
The COMPASS Collaboration

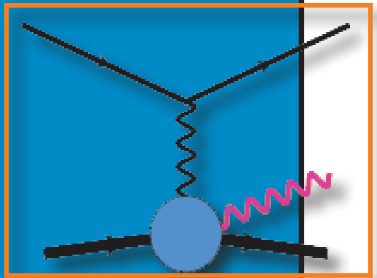
http://wwwcompass.cern.ch/compass/proposal/compass-II_proposal/compass-II_proposal.pdf

COMPASS-II Proposal









EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

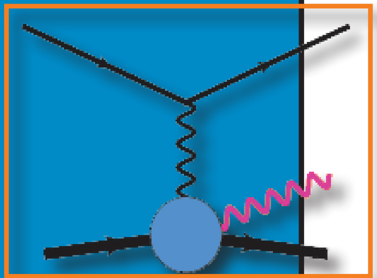
CERN–SPSC–2010–022
SPSC-M-772
September 3, 2010

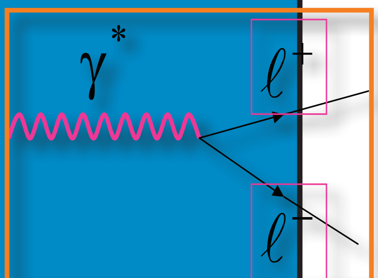
COMPASS-II Proposal: Questions & Answers

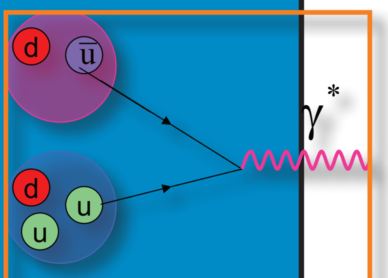
The COMPASS Collaboration

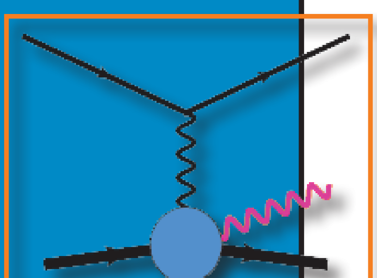
http://wwwcompass.cern.ch/compass/proposal/compass-II_proposal/compass-II_QA_1.pdf

COMPASS-II Proposal









EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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

Approved December 2010

COMPASS-II Proposal

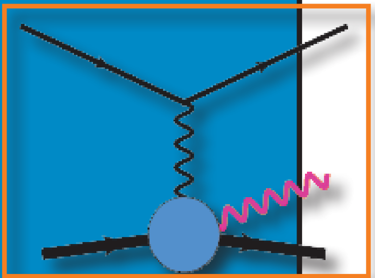
The COMPASS Collaboration

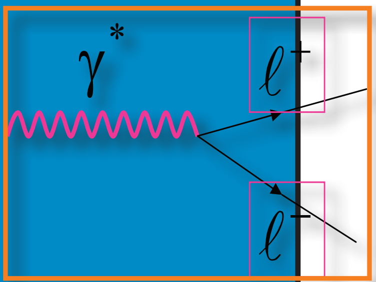
Generalized Parton Distributions (GPDs)

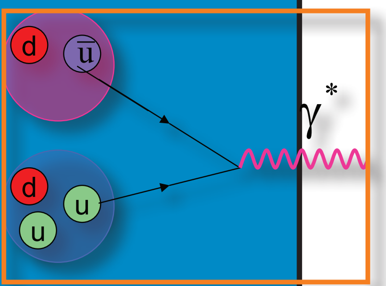
Measurements of unpolarised PDFs and TMD effects in SIDIS

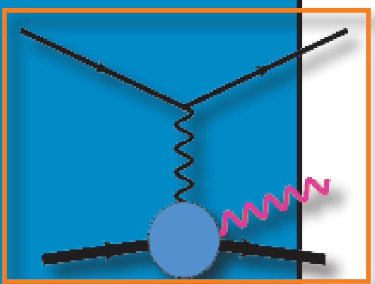
Pion-induced Drell-Yan muon pair production

Primakoff scattering and pion polarisability









EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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

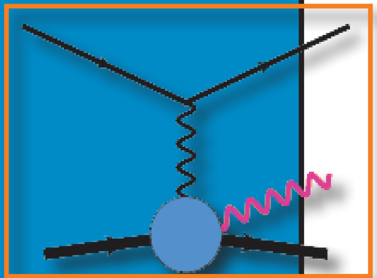
Approved December 2010

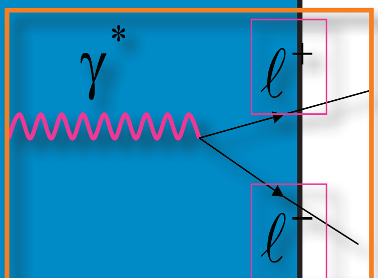
COMPASS-II Proposal

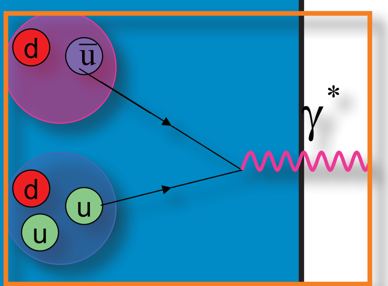
The COMPASS Collaboration

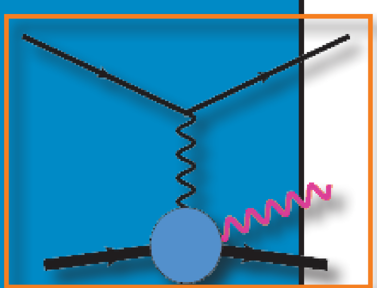
- Generalized Parton Distributions (GPDs)
- Measurements of unpolarised PDFs and TMD effects in SIDIS
- Pion-induced Drell-Yan muon pair production
- **Primakoff scattering and pion polarisability**

COMPASS-II Schedule









COMPASS-II has been recommended by SPSC
and is approved by the Research Board

2012: Primakoff scattering and pion polarisabilities + DVCS test run

2013: SPS long shut-down

2014: Unpolarised and Single polarised DY processes

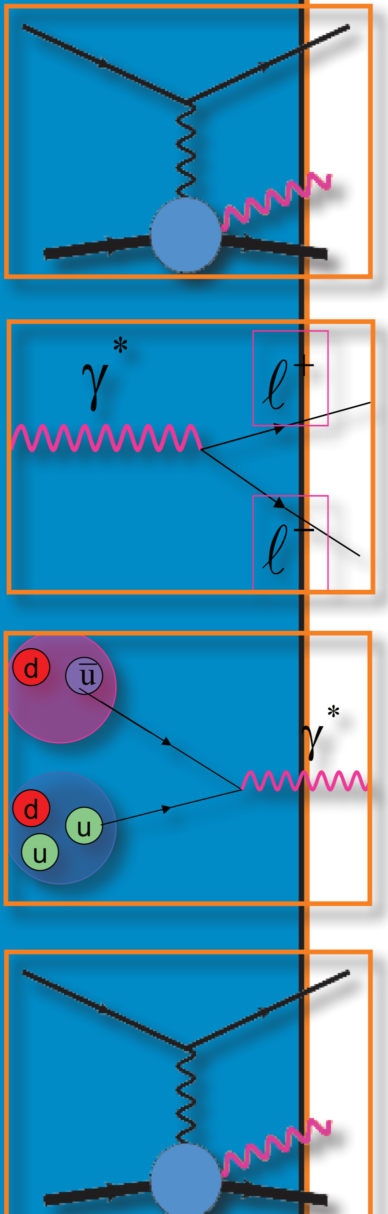
2015/2016: GPDs + in parallel SIDIS

2012:

Primakoff run untill 17 September 2012

Changeover to DVCS

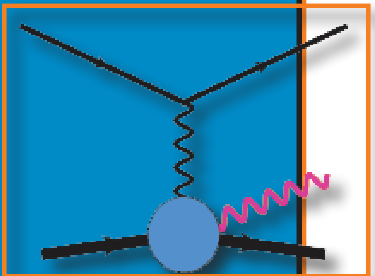
DVCS test run: 08 October - 03 December 2012

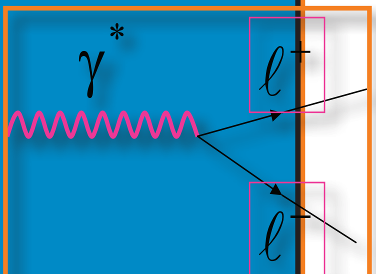


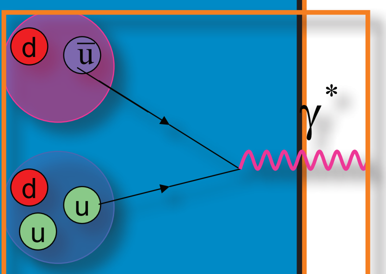
PART I

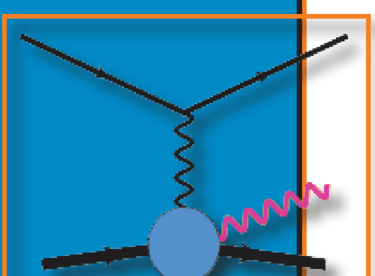
COMPASS-II: GPD programme

GPD and DVCS

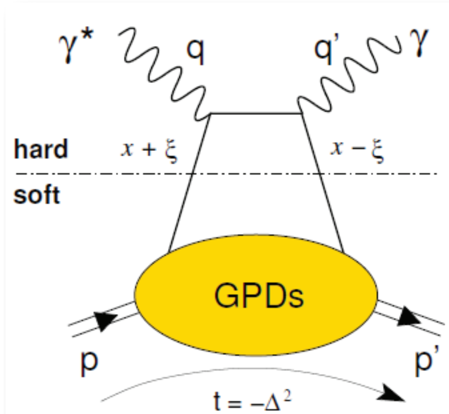








generalised parton distributions for quarks and gluons $\tilde{H}^f$; $\tilde{E}^f$; H^f; E^f (x, ξ, t)



H^f; E^f --> unpolarised distributions

$\tilde{H}^f$; $\tilde{E}^f$ --> polarised distributions

$\tilde{H}^f$; H^f --> conserve nucleon elicity

$\tilde{E}^f$; E^f --> flip nucleon elicity

Factorisation for Q^2 large, $t < 1$ GeV^2

H^f; $\tilde{H}^f$ --> contain as limiting case f_1 and g_1 respectively

Correlating transverse spatial and longitudinal momentum DoF of quark and gluons --> "Nucleon Tomography"

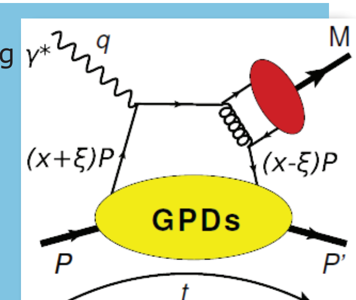
Gluon GPDs enter in DVCS only beyond leading order in α_s (LO)

Ji's relation --> $J^f(Q^2) = \frac{1}{2} \lim_{t \to 0} \int_{-1}^{1} dx \; x \; [H^f(x,\xi,t,Q^2) + E^f(x,\xi,t,Q^2)]$

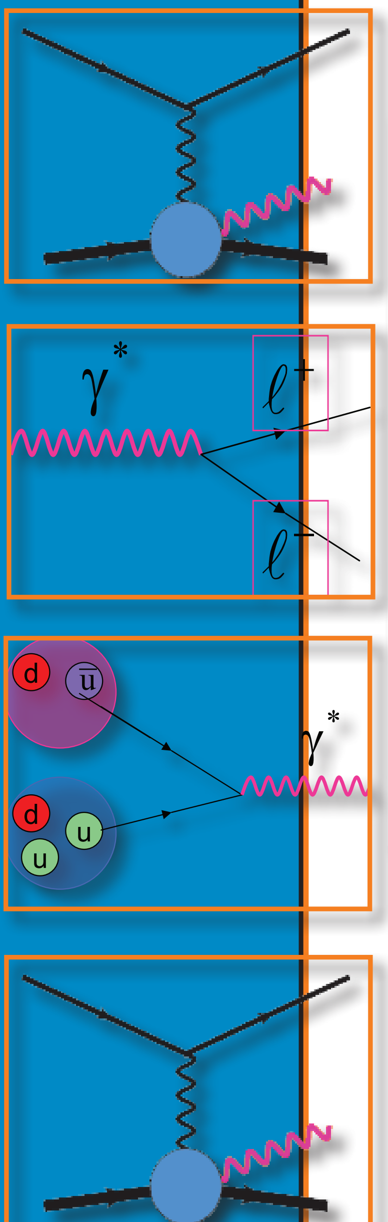
both quark and gluon GPDs contribute at the same order --> H^g

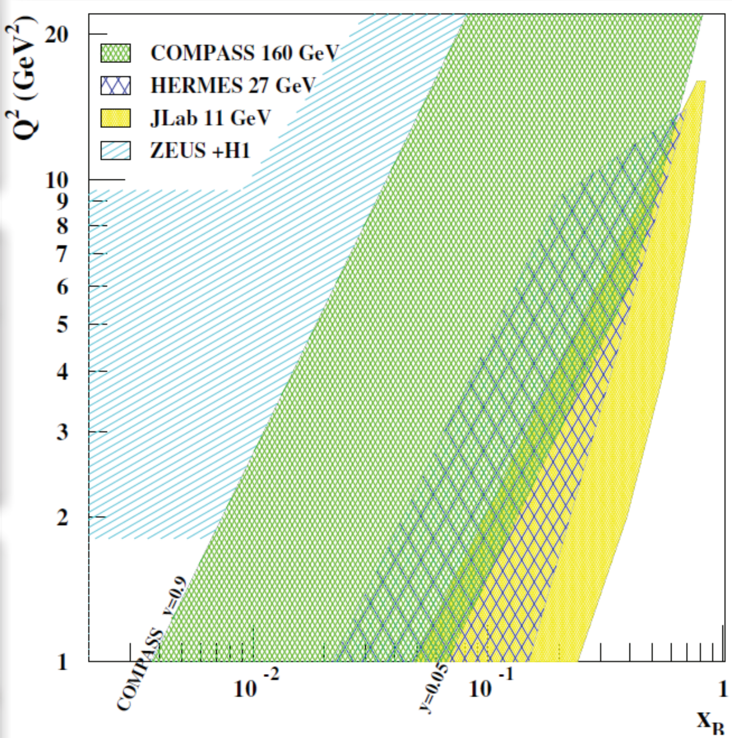
measure of cross sections for a large set of mesons (ρ,ω,φ,..)
--> different combinations of quark and gluon GPDs

Nucleaon tomography --> complementary information to DVCS



GPD and DVCS at COMPASS - II





Coverage of intermediate x_{Bj} region

↓

exploring the uncharted territory in between the collider Zeus + H1 region and that of the lower-energy fixed-target Hermes/JLab experiments.

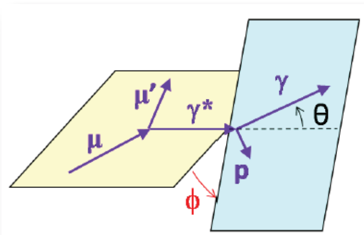
μ^+ , μ^- beam

momentum: 160 GeV/c

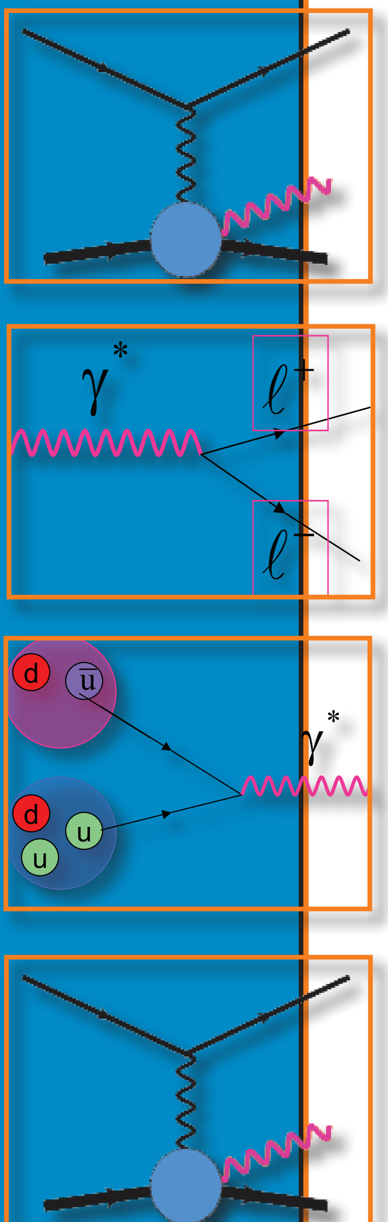
Beam polarisation 80% opposite for μ^+ , μ^-

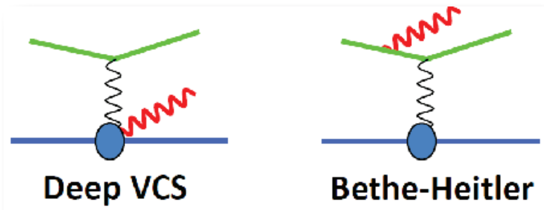
↓

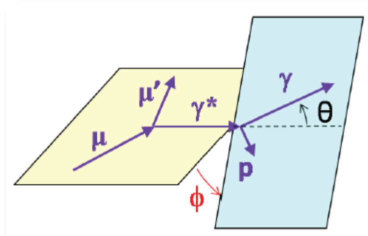
Beam Charge and Spin Sum/Difference of $d\sigma(\mu p \to \mu' p' \gamma)$:
study of its ϕ dependence



$\mu p \to \mu' p' \gamma$: interference with Bethe-Heitler





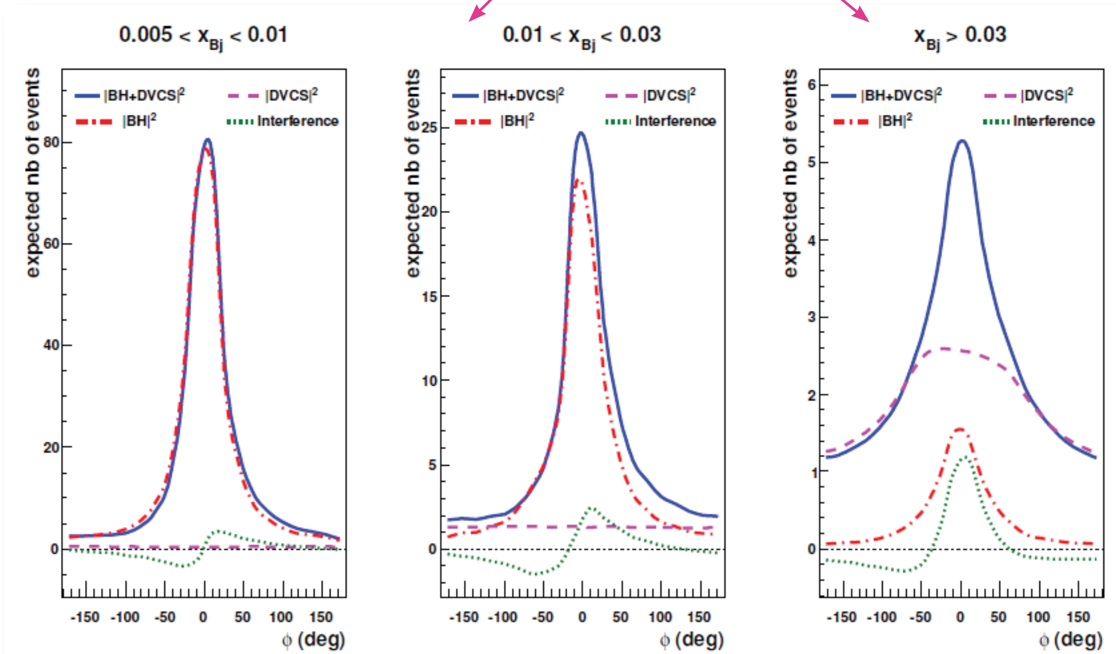


Int. term --> real and imaginary parts of DVCS amplitude

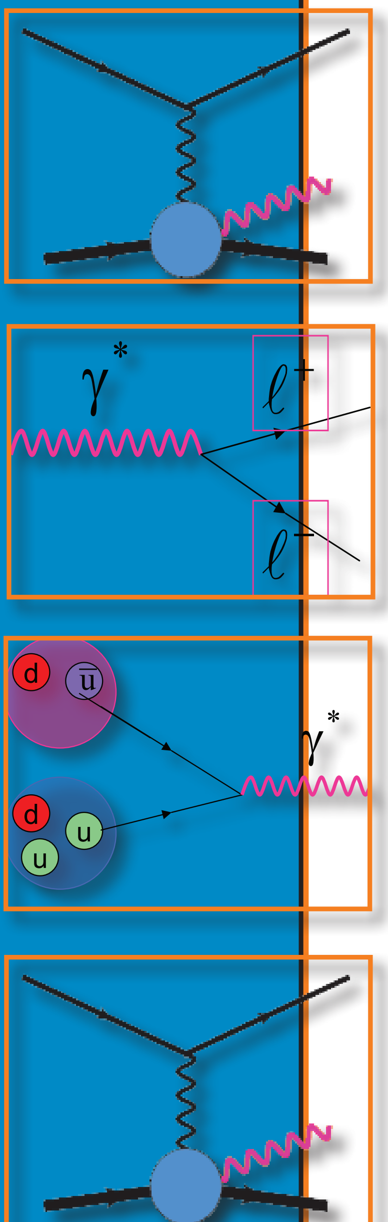
$$d\sigma_{(\mu p \to \mu' p' \gamma)} = d\sigma^{BH} + \text{Interference Term} + d\sigma^{DVCS}$$

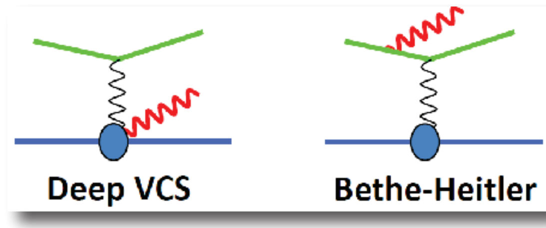
BH dominance: reference yield

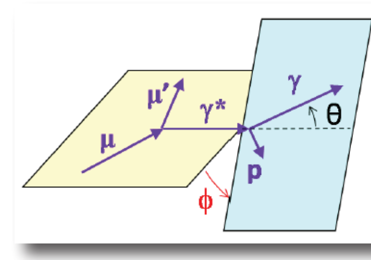
DVCS dominance



μp -> μ′p′γ: interference with Bethe-Heitler







$$d\sigma_{(\mu p \to \mu' p' \gamma)} = d\sigma^{BH} + \left(d\sigma^{DVCS}_{unpol} + P_\mu\, d\sigma^{DVCS}_{pol}\right) + e_\mu \left(\mathrm{Re}\, I + P_\mu\, \mathrm{Im}\, I\right)$$

COMPASS: opposite polarisation of μ^+ , μ^- beam

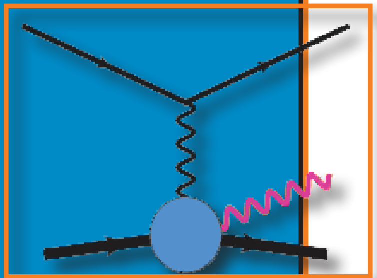
Beam charge and spin sum:

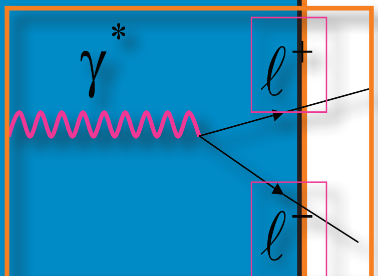
$$\mathcal{S}_{CS,U} \equiv d\sigma^{\overleftarrow{+}} + d\sigma^{\overrightarrow{-}} = 2(d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + e_\mu P_\mu \mathrm{Im}\, I)$$

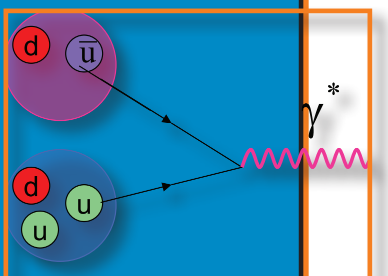
Beam charge and spin difference:

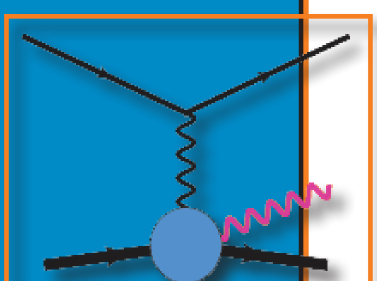
$$\mathcal{D}_{CS,U} \equiv d\sigma^{\overleftarrow{+}} - d\sigma^{\overrightarrow{-}} = 2(P_\mu d\sigma^{DVCS}_{pol} + e_\mu \mathrm{Re}\, I)$$

Transverse size of the nucleon









Beam charge and spin sum:

$$\mathcal{S}_{CS,U} \equiv \mathrm{d}\sigma^{\overleftarrow{+}} + \mathrm{d}\sigma^{\overrightarrow{-}} = 2(\mathrm{d}\sigma^{BH} + \mathrm{d}\sigma^{DVCS}_{unpol} + e_\mu P_\mu \mathrm{Im}\, I)$$

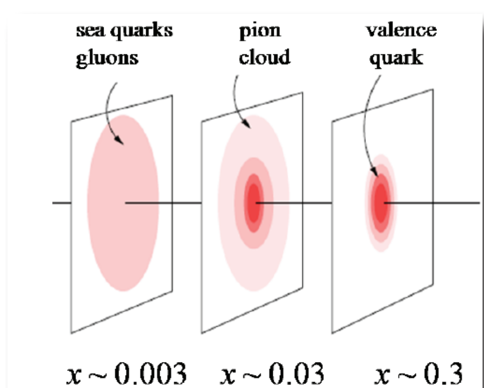
Integrating over ϕ and subtrating BH:

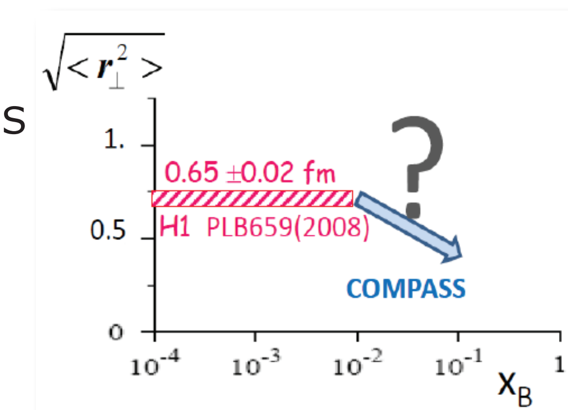
$$\begin{aligned} \mathcal{S}_{CS,U} &= 2\frac{\Gamma(x_B,Q^2,t)}{\mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}\left(c_0^{BH} + c_1^{BH}\cos\phi + c_2^{BH}\cos 2\phi\right) \\ &+ 2\frac{e^6}{y^2Q^2}\left(c_0^{DVCS} + \{c_1^{DVCS}\cos\phi + c_2^{DVCS}\cos 2\phi\}\right) \\ &+ 2e_\mu P_\mu \frac{e^6}{x_B y^3 t \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}\left(s_1^I \sin\phi + \{s_2^I \sin 2\phi\}\right). \end{aligned}$$

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

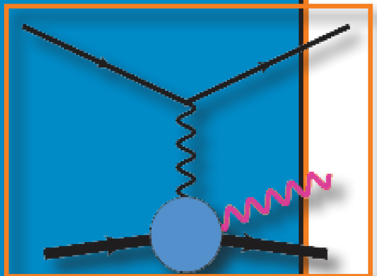
$B(x_B) \sim 1/2 \langle r_\perp^2(x_B)\rangle$

The transverse size $r_\perp^2$ as function of x_B can be extracted in a model-independent way from the t-slope of the measured DVCS cross-section --> "Nucleon Tomography"



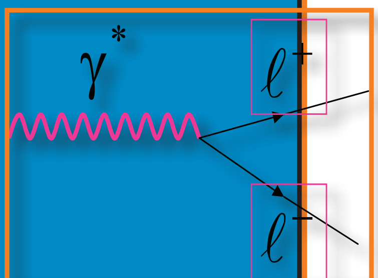


Transverse size of the nucleon

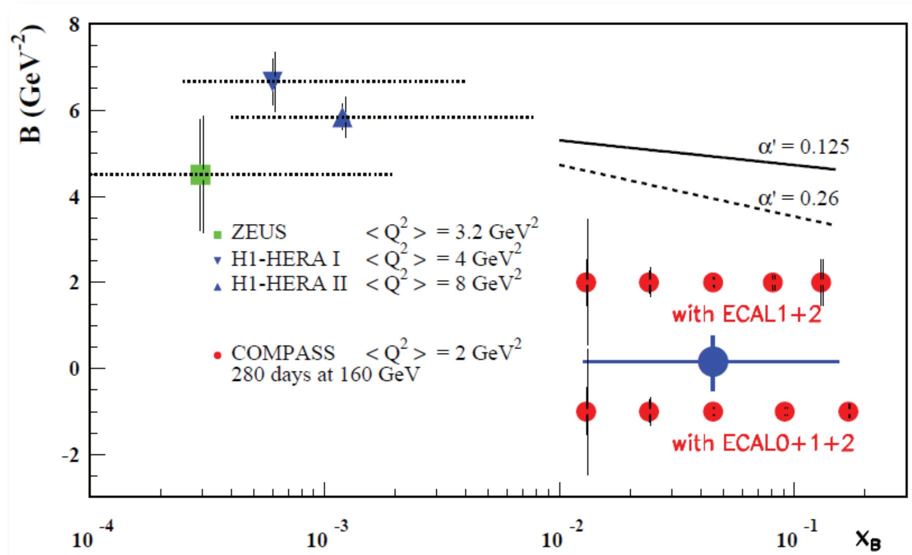


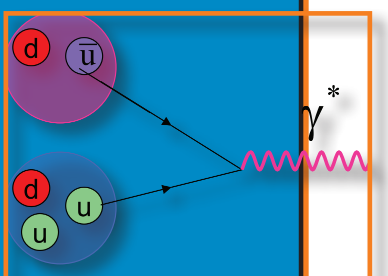
$B(x_B) \sim 1/2 \langle r_\perp^2(x_B) \rangle$

Ansatz at small x_B: $B(x_B) \sim b_0 + 2\alpha' \log (x_0 / x_B)$



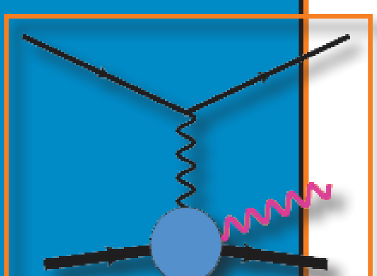
Projection with:
L = 1222 pb^{-1}
2 years of data taking
160 GeV/c muon beam
2.5m LH_2 target
$\varepsilon = 10\%$





Accuracy>2.5σ for:

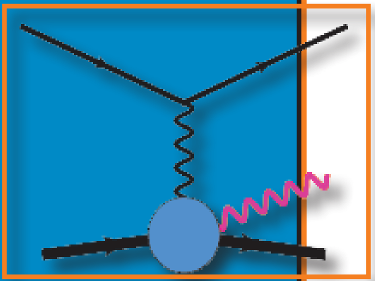
$\alpha' > 0.26$ (with ECAL1+2)
$\alpha' > 0.125$ (with ECAL0+1+2)

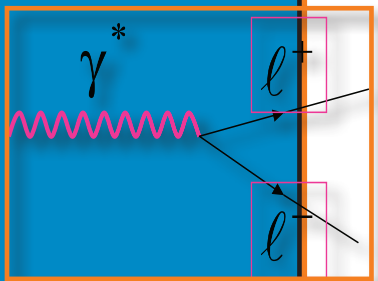


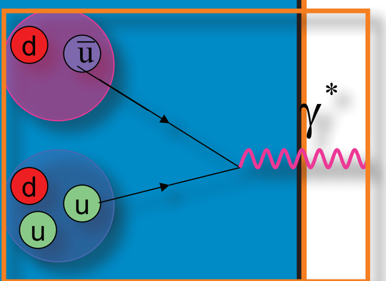
In 2012 we can determine one mean value of B

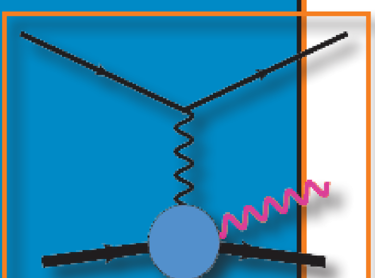
Systematic errors dominated by BH subtraction at low x_B

Φ dependence: example beam charge and spin difference









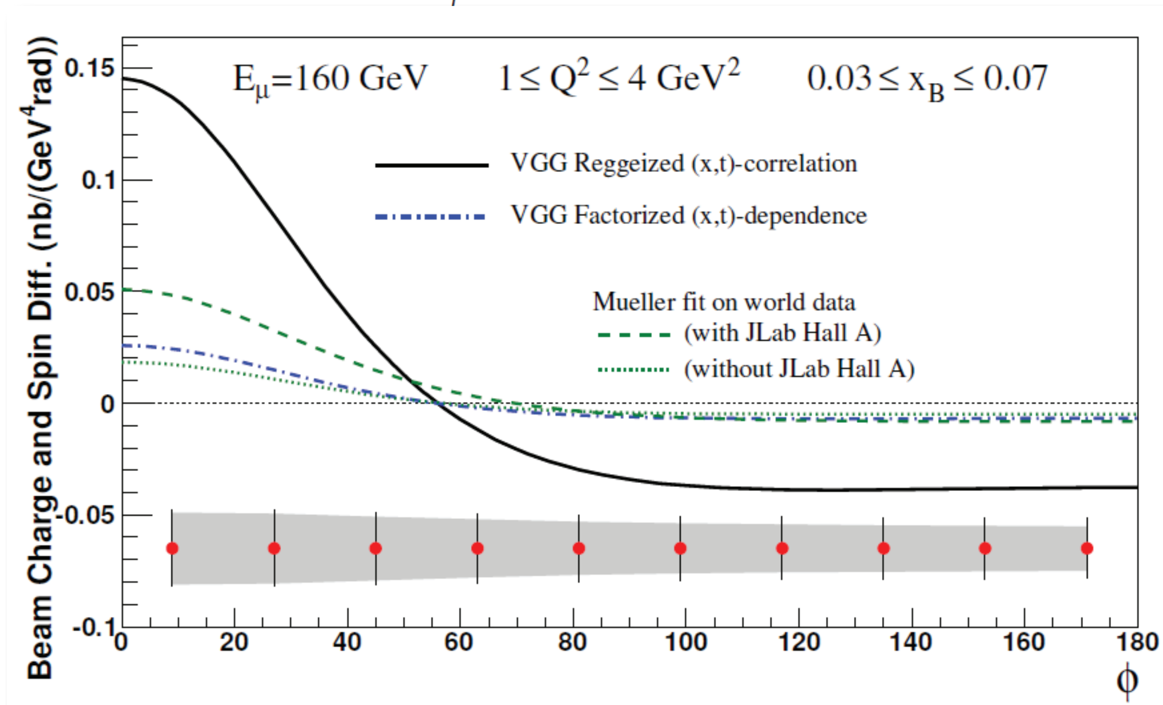
Beam charge and spin difference:

$$\mathcal{D}_{CS,U} \equiv d\sigma^{\overleftarrow{+}} - d\sigma^{\overrightarrow{-}} = 2(P_\mu d\sigma^{DVCS}_{pol} + e_\mu \mathrm{Re}\ I)$$

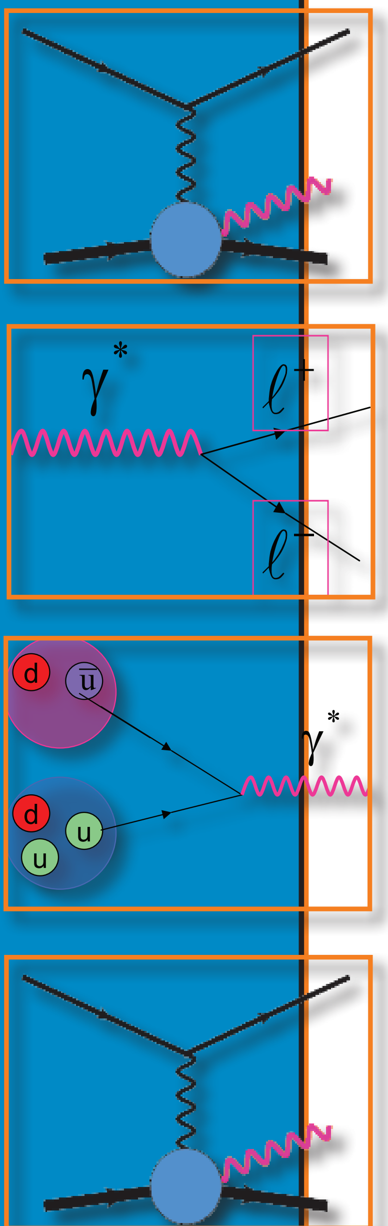
BH contribution cancels

$$\propto c_0^I + c_1^I \cos\phi \quad c_1^I \propto \mathrm{Re}\,(F_1 \mathcal{H})$$

$$\mathrm{Re}\,\mathcal{H}(\xi, t, Q^2) \overset{\mathrm{LO}}{=} \sum_f e_q^2 \left[\mathcal{P} \int_{-1}^{1} dx\ H^f(x, \xi, t, Q^2) \left(\frac{1}{x-\xi} \mp \frac{1}{x+\xi} \right) \right]$$



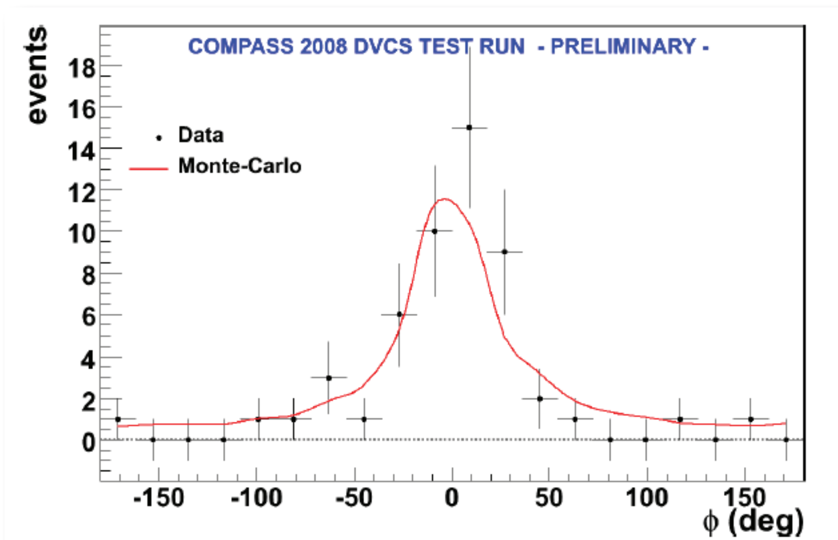
2008 - 2009 DVCS Beam Test



Beam tests @COMPASS during hadron program

2008:
160 GeV/c μ^+, μ^- beam
40cm LH target + 1m long Recoil Proton Detector
1/3 of maximum intensity
BMS not installed

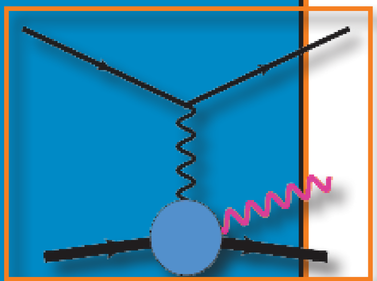
Goal: observation of exclusive single photon production

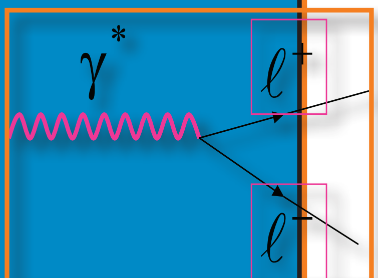


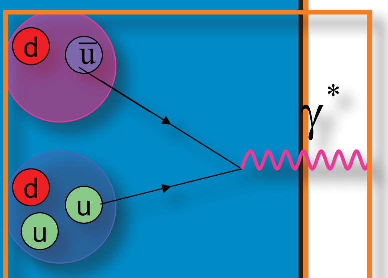
$\varepsilon_{\mu\pi\to\mu' p'\gamma} = 0.32 \pm 0.13$

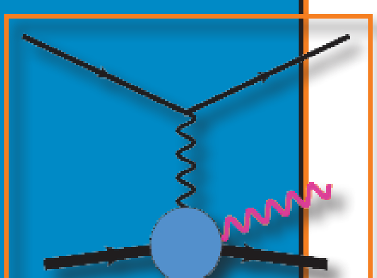
$\varepsilon_{global} = 0.13 \pm 0.05$

2008 - 2009 DVCS Beam Test







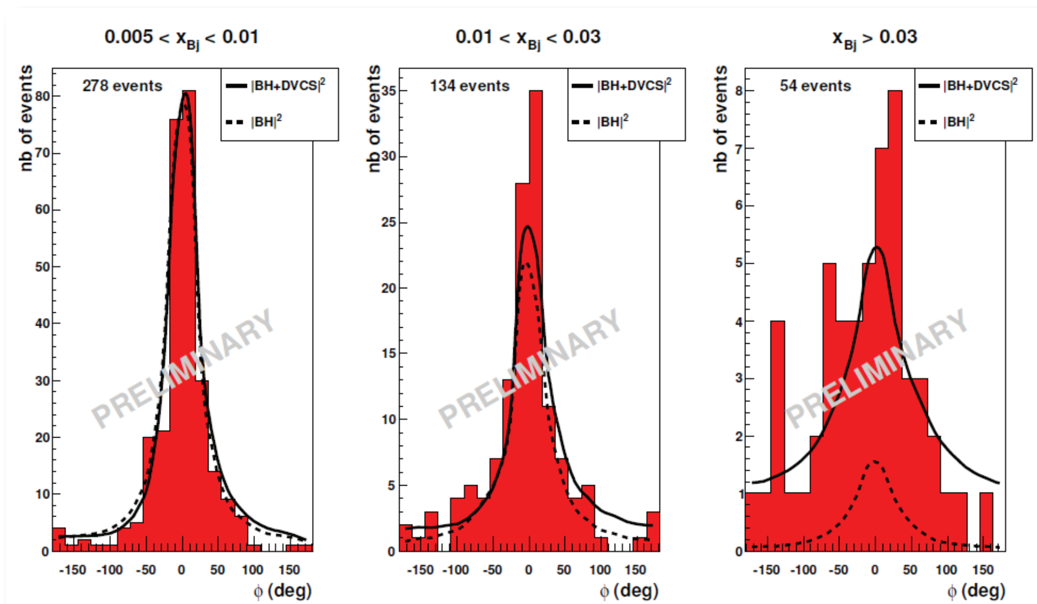


Beam tests @COMPASS during hadron program

2009 --> improved test run:

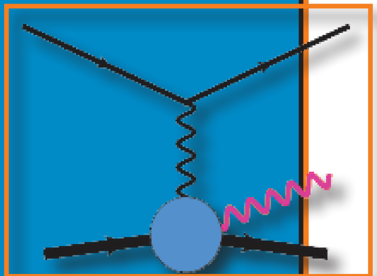
- higher statistics
- the three inclusive triggers (Middle, Ladder, Outer) added in coincidence with the RPD
- BMS reinstalled
- beam intensity increased by a factor of three

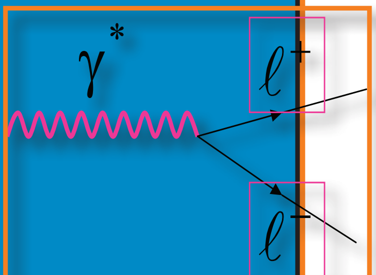
goal: First evaluation of $|DVCS|^2$, $|BH|^2$ and I Term @COMPASS kinematics

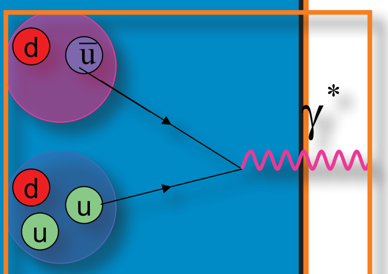


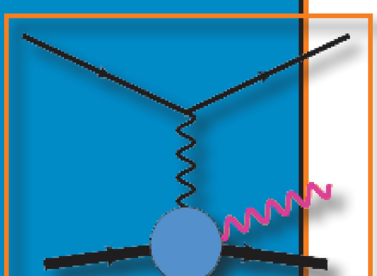
excess of events for $x_B > 0.03$ --> DVCS events

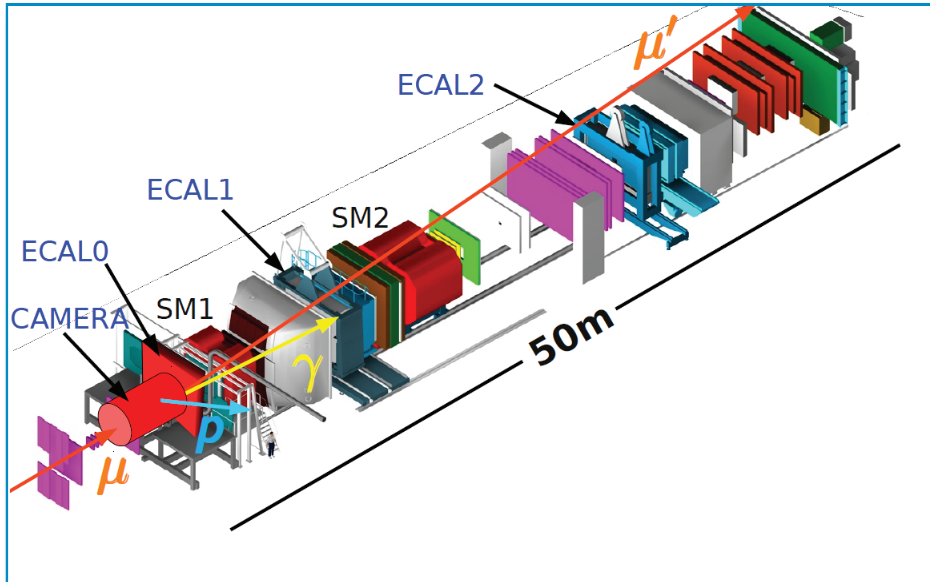
The COMPASS Spectrometer for DVCS









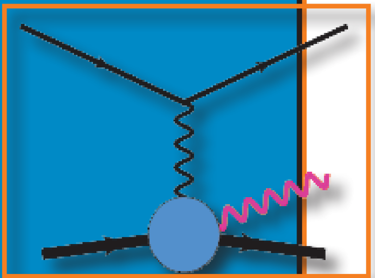


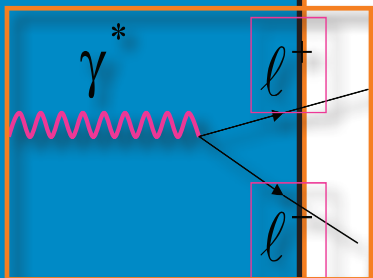
New hardware developments:

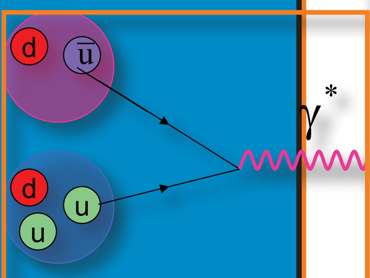
- 2.5 m liquid hydrogen target
- 4 m recoil proton detector (CAMERA)
- New large angle electromagnetic calorimeter (ECAL0)

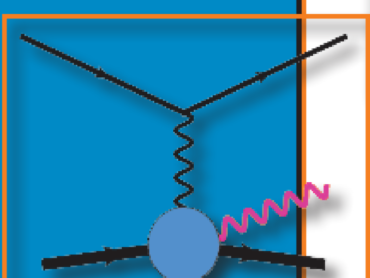
Upgrades of ECAL1 and ECAL2

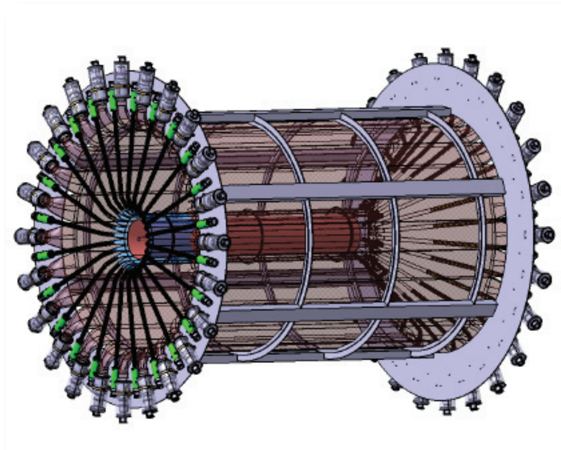
New Hardware Developments











4 m Recoil Proton Detector:

two ToF barrels of 24 scintillator slats readout at both ends

+ 1 GHz digitization of the PMT signal to cope for high rate (GANDALF boards)

2.5m LH_2 target

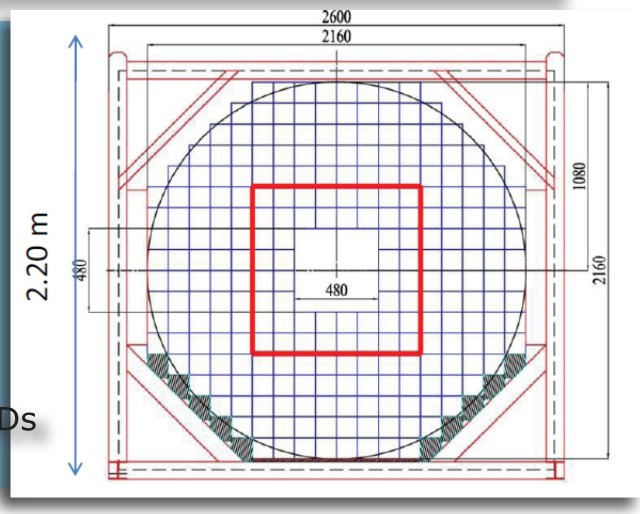
New large angle electromagnetic calorimeter ECAL0:

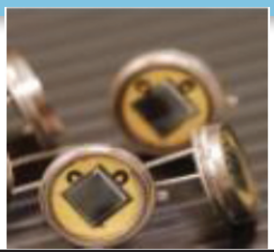
Energy range for photon detection: 0.2 to 30 GeV.

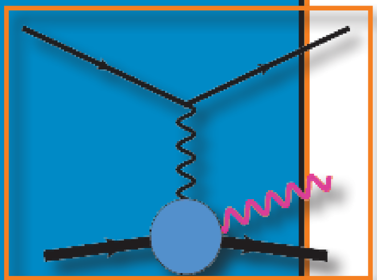
Energy resolution is about 10% at 1 GeV or better

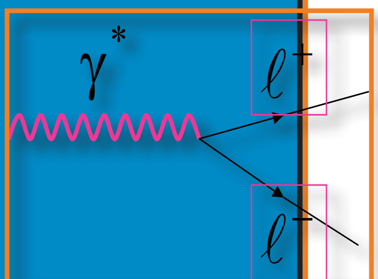
Multipixel Avalanche Photodiode readout

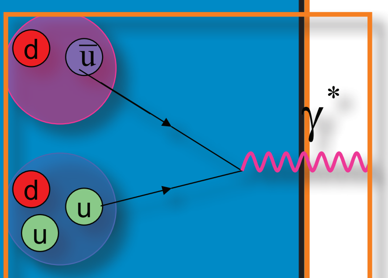
248 modules (12 x 12 cm^2) of 9 cells read by 9 MAPDs

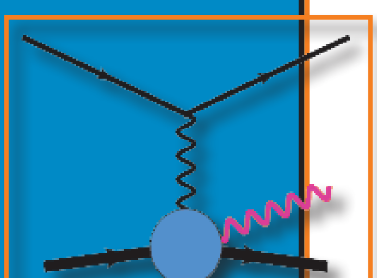








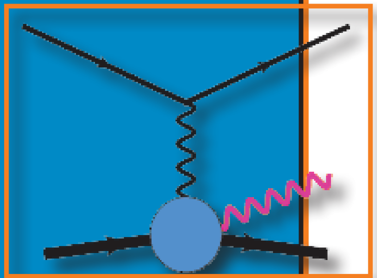


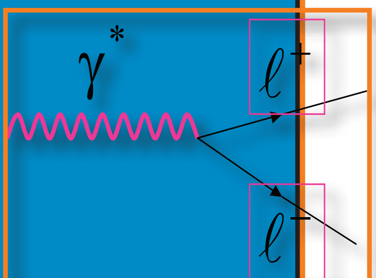


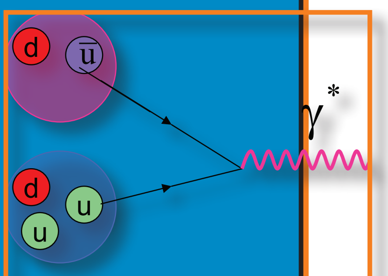
PART II

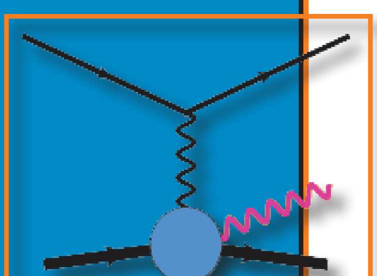
Semi-Inclusive DIS (in parallel with GPD programme)

Measurements of unpolarised PDFs and FFs in SIDIS









See G. Sbrizzai's talk for more details about unpolarised azimuthal asymmetries in SIDIS at COMPASS (S3-I, 18 September)

COMPASS I: ^{6}LiD and NH_3

COMPASS II: pure hydrogen target in parallel with DVCS and DVMP; 160 GeV/c muon beam

Goal:
Identified hadron multiplicities measurements:

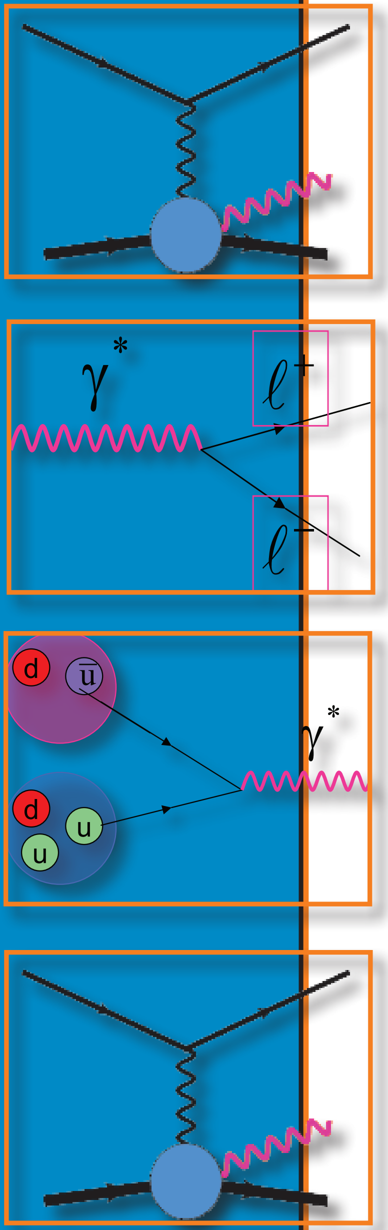
$$\frac{dN^h(x,z,Q^2)}{dN^{DIS}} = \frac{\sum_q e_q^2 q(x,Q^2) D_q^h(z,Q^2)}{\sum_q e_q^2 q(x,Q^2)}$$

- flavor separation
- study of 4-dimensional dependencies in the kinematic variables x, Q^2, p_T^2 and z

These SIDIS data will be used in global QCD analyses to constrain PDFs and FFs

Direct LO determination of the unpolarised strange quark distribution function s(x) in the region $0.01 < x < 0.2$, where its shape is unknown

Measurements of unpolarised PDFs and FFs in SIDIS

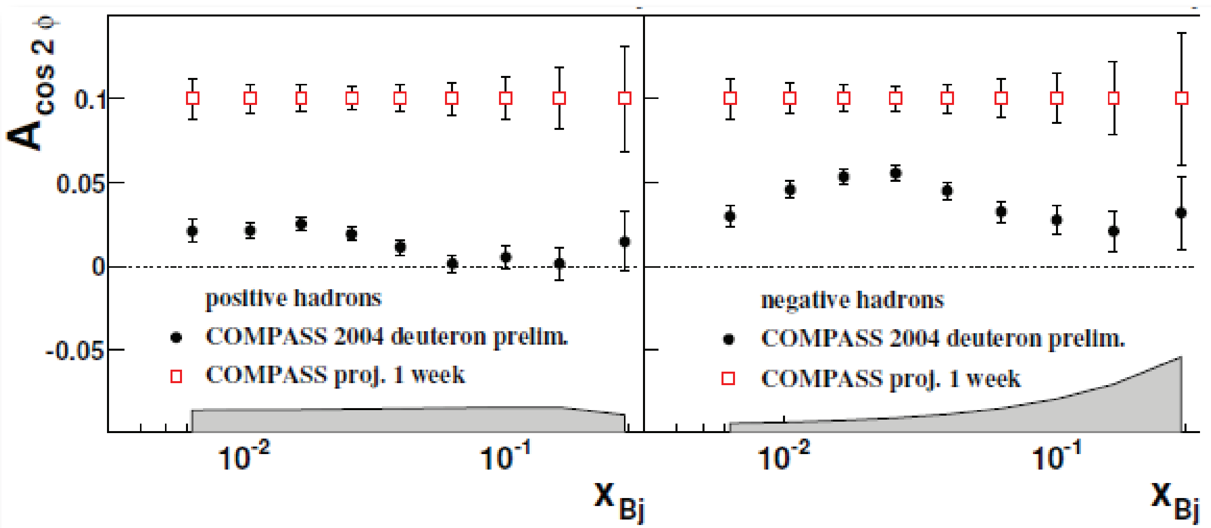


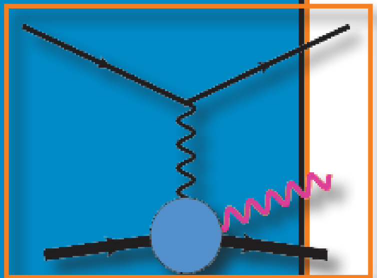
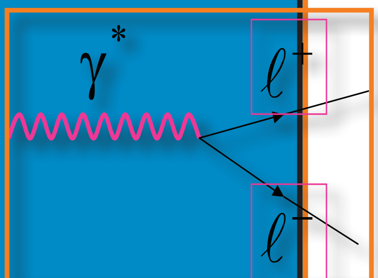
In SIDIS on an unpolarised target, hadron azimuthal asymmetries arise that give access to the distribution of intrinsic quark k_T as encoded in the T-odd Boer-Mulders function and also to higher-twist effects

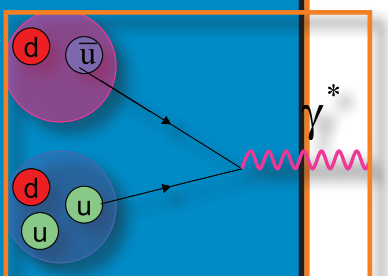
$$\frac{d\sigma}{dx\,dy\,d\phi_h} = \frac{\alpha^2}{xyQ^2}\frac{1+(1-y)^2}{2}\Big[F_{UU} + \varepsilon_1 \cos\phi_h F_{UU}^{\cos\phi_h} + \varepsilon_2 \cos 2\phi_h F_{UU}^{\cos 2\phi_h} + \lambda_\mu \varepsilon_3 \sin\phi_h F_{LU}^{\sin\phi_h}\Big],$$

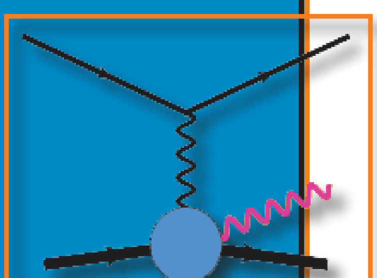
Cahn effect

Boer-Mulders TMD Collins FF + Cahn effect



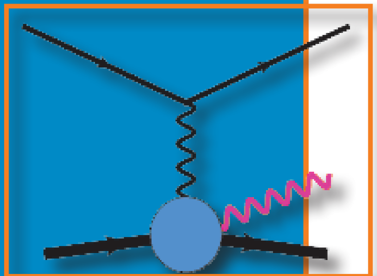


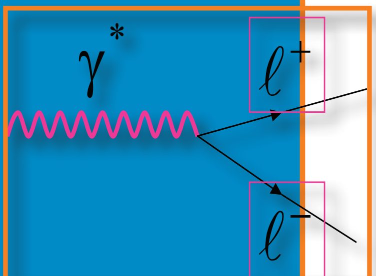


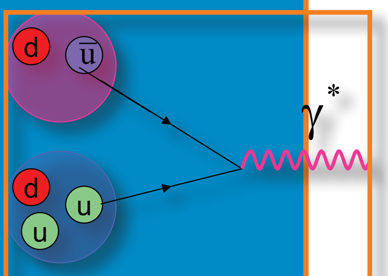
PART III

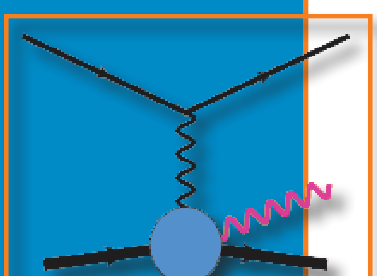
Drell-Yan Programme

Single polarized Drell-Yan







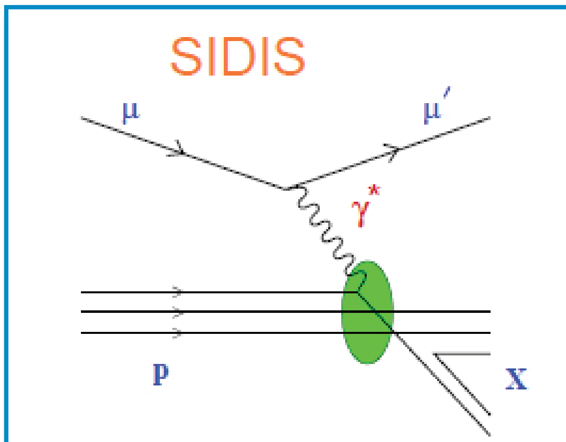


- Transversity and TMD PDFs
- TMDs universality
- J/ψ-Drell-Yan duality

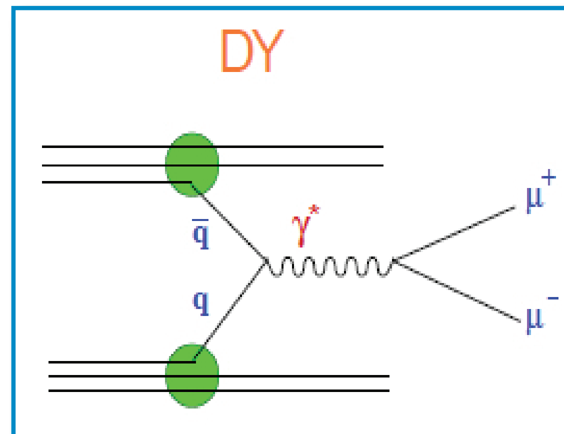
See M. Quaresma and O. Denisov talks for more details about DY@COMPASS-II (S8III, September 21)

Unpolarised Drell-Yan

TMD PDFs, like Sivers, can be accessed both from semi-inclusive DIS (SIDIS) and from the Drell-Yan process (DY).

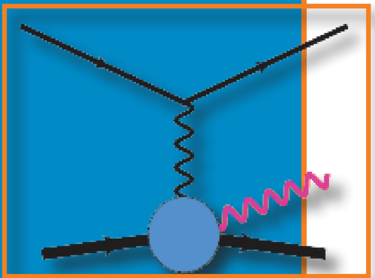


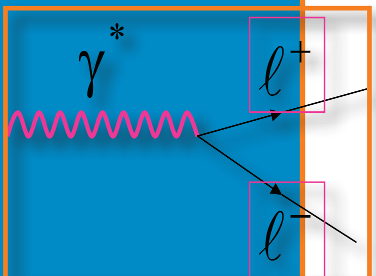
the amplitudes of azimuthal modulations are convolutions of PDFs and FFs

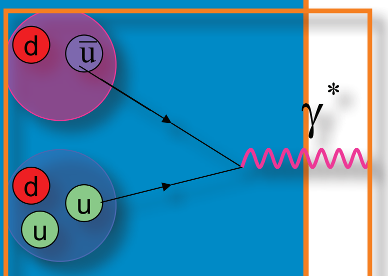


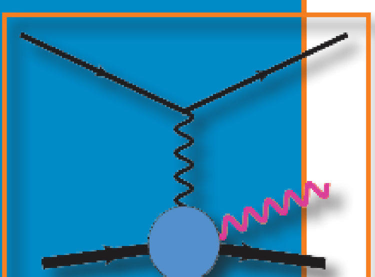
the amplitudes of azimuthal modulations are convolutions of PDFs only

Single polarized Drell-Yan









In a recent paper Arnold, Metz and Schlegel derived the full expression of the Drell-Yan cross-section, including unpolarized, transversely and longitudinally polarized terms [S. Arnold et al, Phys.Rev. D79 (2009)034005].

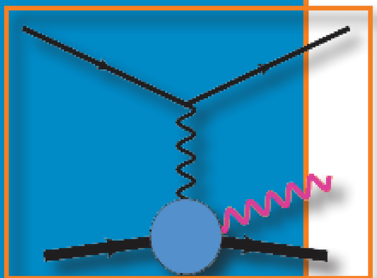
In single polarized DY, with transversely polarized target nucleons, the general expression of the cross-section (LO) is:

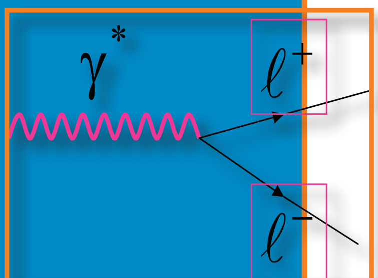
$$\frac{d\sigma}{d^4q\,d\Omega} = \frac{\alpha_{em}^2}{Fq^2}\hat{\sigma}_U\{(1 + D_{[\sin^2\theta]}A_U^{\cos 2\phi}\cos 2\phi) + |\vec{S}_T|[A_T^{\sin\phi_S}\sin\phi_S + D_{[\sin^2\theta]}(A_T^{\sin(2\phi+\phi_S)}\sin(2\phi+\phi_S) + A_T^{\sin(2\phi-\phi_S)}\sin(2\phi-\phi_S))]\}$$

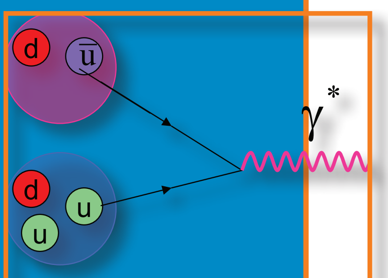
A: azimuthal asymmetries; D: depolarization factor; S: target spin components; F: flux of incoming hadrons; σ_U: part of the cross-section surviving integration over ϕ and ϕ_S

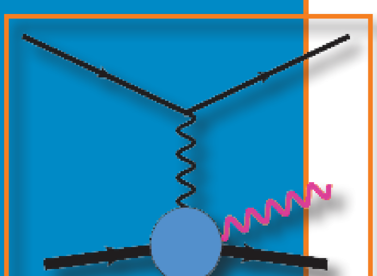
ϕ : azimuthal angle of transverse target spin S_T in the target rest frame
ϕ_S : azimuthal angle of the lepton momenta in the Collins-Soper frame

Single Polarized Drell-Yan







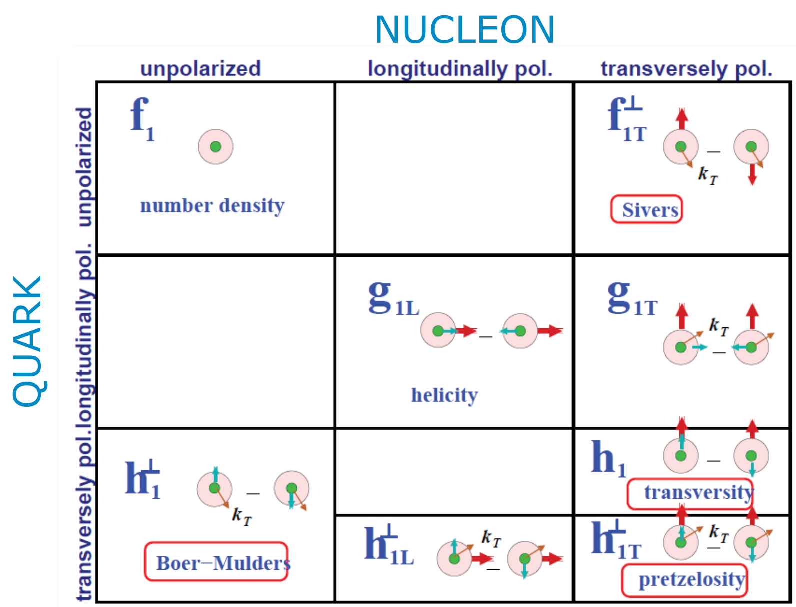


$A_U^{\cos 2\phi}$ gives access to the Boer-Mulders functions of the incoming hadrons

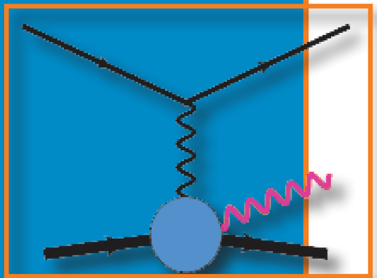
$A_T^{\sin\phi_S}$ to the Sivers function of the target nucleon

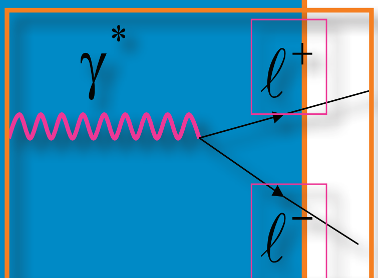
$A_T^{\sin(2\phi+\phi_S)}$ to the Boer-Mulders function of the beam hadron and to the pretzelosity function of the target nucleon

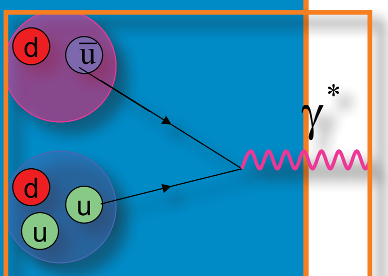
$A_T^{\sin(2\phi-\phi_S)}$ to the Boer-Mulders function of the beam hadron and to the transversity function of the target nucleon

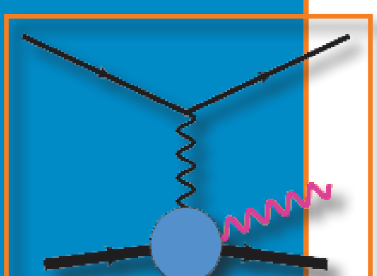


DY vs SIDIS







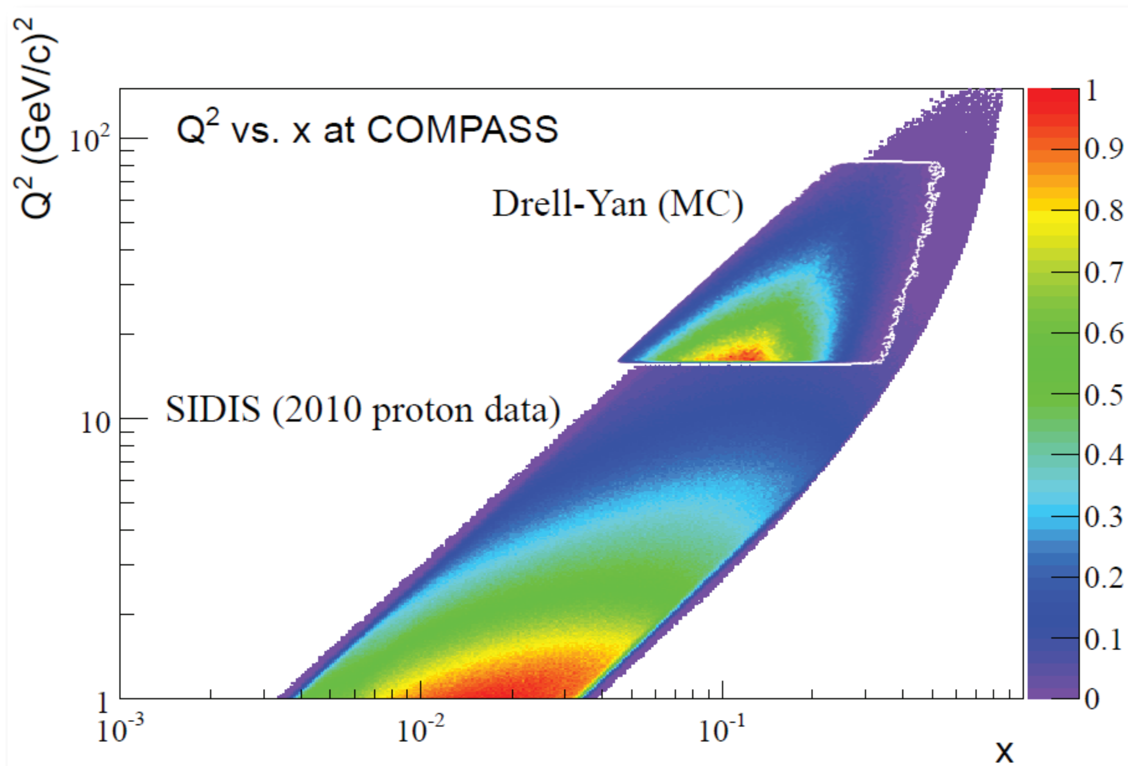


Change of sign of Sivers and Boer-Mulders functions?

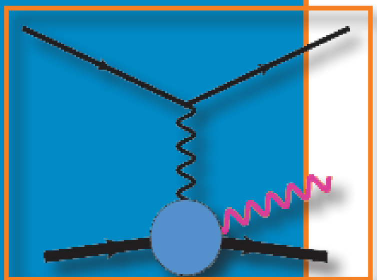
$$f_{1T}^{\perp}\Big|_{DY} = -f_{1T}^{\perp}\Big|_{DIS} \qquad \text{and} \qquad h_1^{\perp}\Big|_{DY} = -h_1^{\perp}\Big|_{DIS}$$

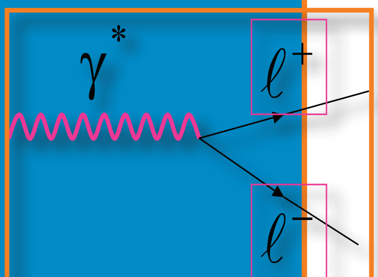
Critical test of universality of TMD factorization approach for the description of SSA.

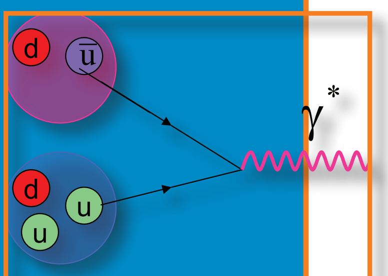
In COMPASS, we have the opportunity to test this sign change using the same spectrometer and a transversely polarized target.

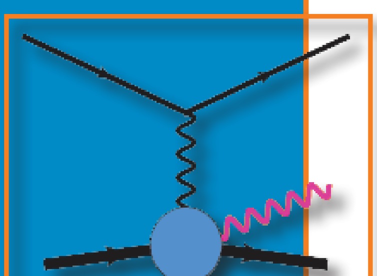


Polarized Drell-Yan experiments









What do we need to access spin dependent PDFs through DY?

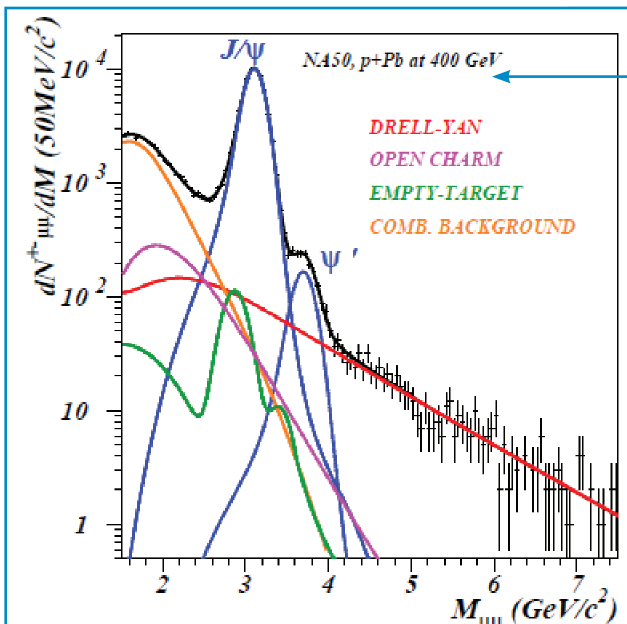
Polarized Drell-Yan experiments:

- High luminosity (DY Cross Section is a fraction of nanobarns) and large angular acceptance

- Sufficiently high energy to access 'safe' background free M range (4 GeV/c^2 < $M_{\mu\mu}$< 9 GeV/c^2)

- Good acceptance in the valence quark range

- Good figure of merit (FoM), which can be represented as a product of the luminosity, target polarisation (dilution factor f) and beam (target) polarisation



NA50: p @ 400 GeV/c in a Pb target; I about 10^9 particles/sec

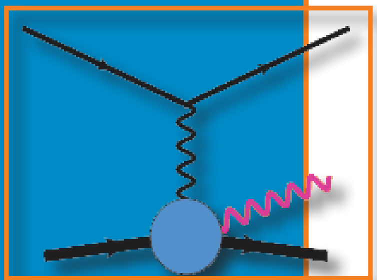
Even if the cross-section is low, M range 4 < $M_{\mu\mu}$ < 9 GeV/c^2 is the ideal sample to study azimuthal asymmetries in Drell-Yan, due to negligible background contamination.

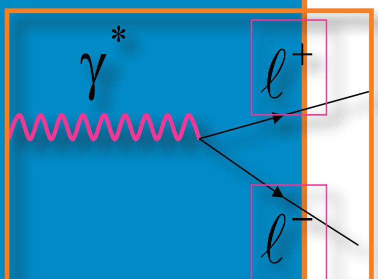
The combinatorial background is kept under control by the presence of a hadron absorber downstream of the target.

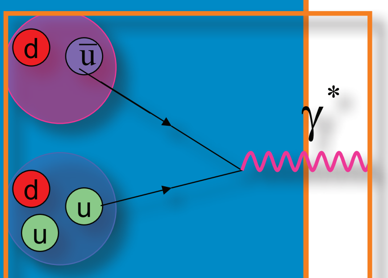
@ COMPASS: π^- @ 190 GeV/c in a NH_3 target; I up to 10^8 particles/sec: comb. background 100 times lower (50% of total in intermediate M range 2. < $M_{\mu\mu}$ < 2.5 GeV/c^2)

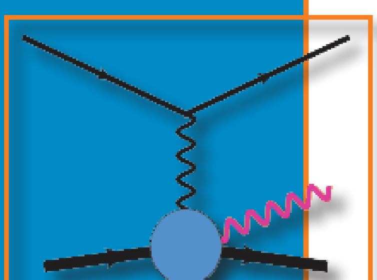
open charm contributes only at 15%

Drell-Yan @ COMPASS-II

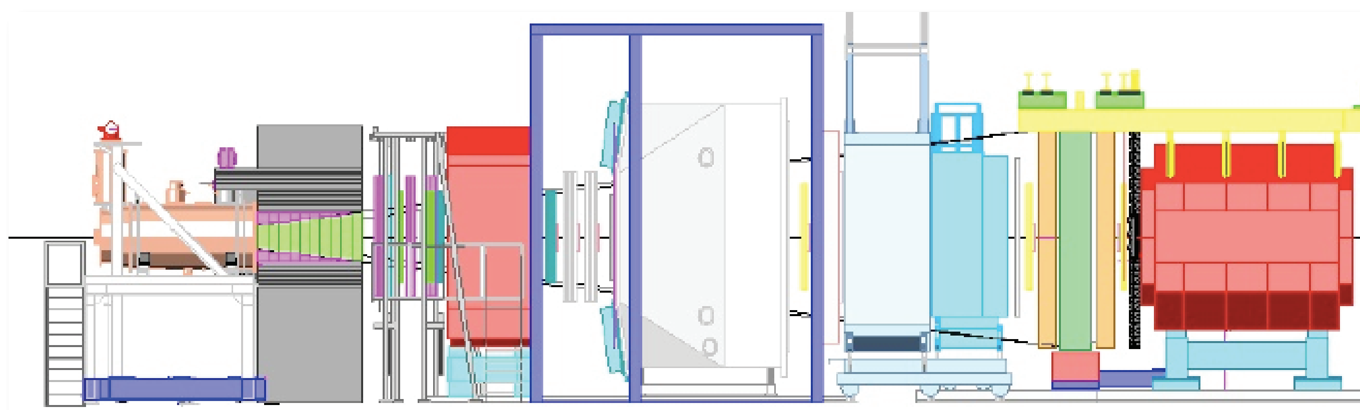




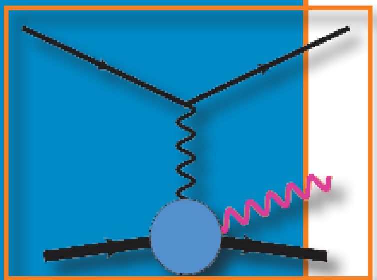


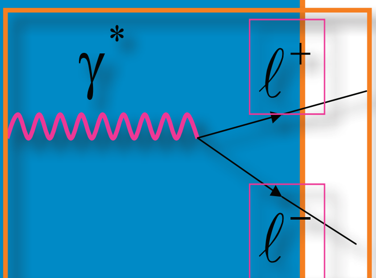


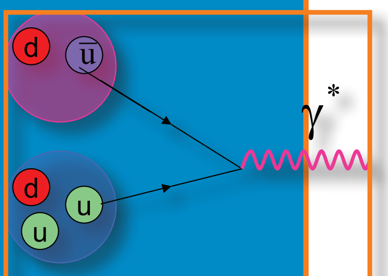
- Large angular acceptance spectrometer
- π^- beam at 190 GeV/c with the intensity up to 1x10^8 particles/second
- Large acceptance COMPASS Superconducting Solenoid Magnet
- Transversely polarized NH_3 target working in frozen spin mode with long relaxation time
- Hadron absorber downstream of the target
- A detection system designed to stand relatively high particle fluxes
- A Data Acquisition System (DAQ) that can handle large amounts of data at large trigger rates
- Trigger based on hodoscope signals coincidence, homothetic and pointing to the target

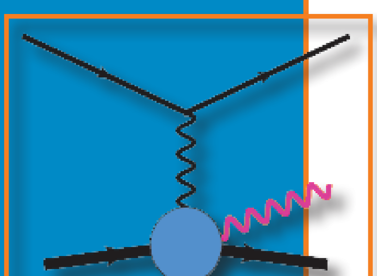


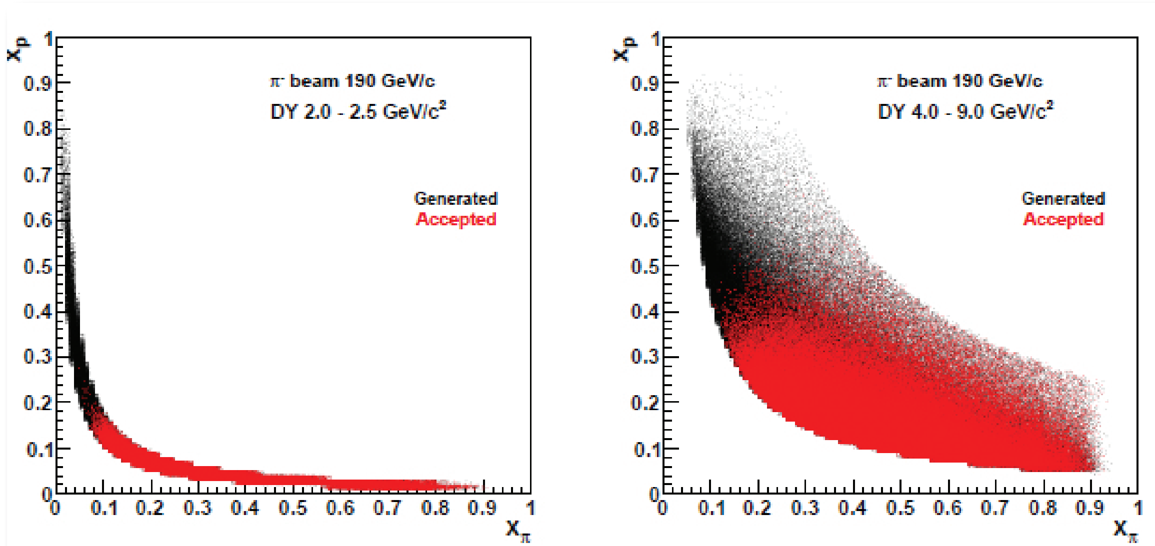
COMPASS-II DY Acceptance





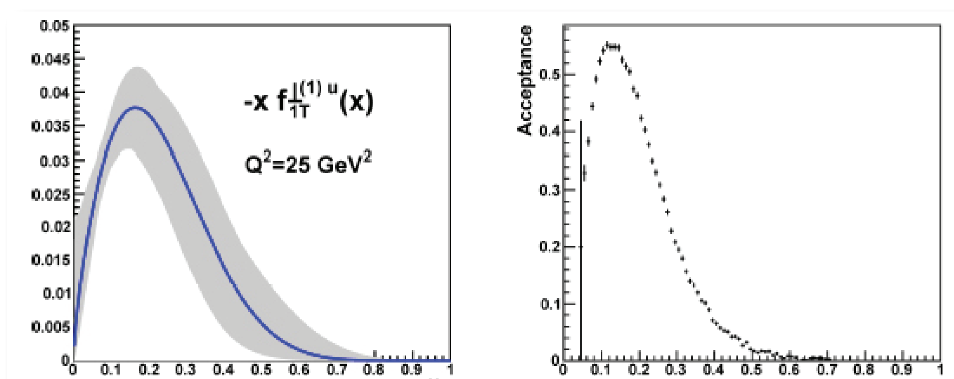






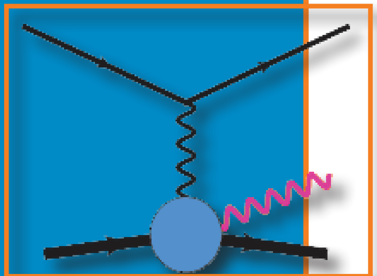
COMPASS acceptance is in the valence quarks region

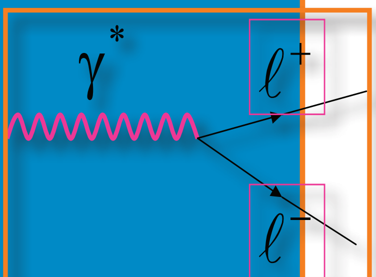
For DY 4 < $M_{\mu\mu}$ < 9 GeV/c^2, we have x_p > 0.05 --> also the best region to measure spin asymmetries

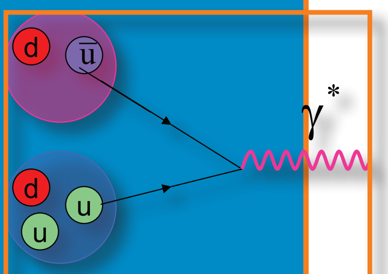


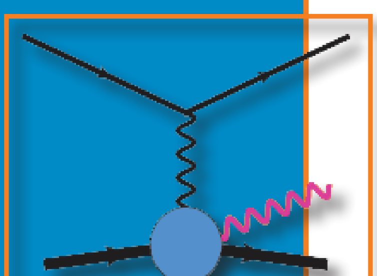
M. Anselmino et al., Eur. Phys. J. A39 (2009) 89.

Drell-Yan @ COMPASS-II: Feasibility









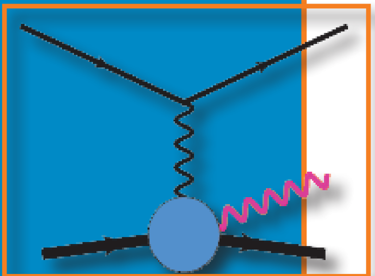
In 2007, 2008 and 2009 short Drell-Yan beam tests were performed, to check the feasibility of the measurement

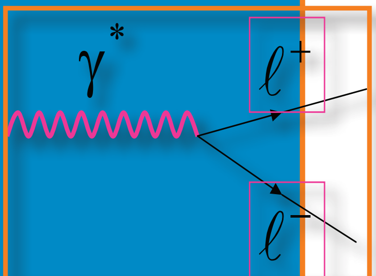
In 2007, with a π^- beam of 160 GeV/c on a NH_3 target, and without hadron absorber: ≈ 90000 dimuon events (< 12 hours data-taking)

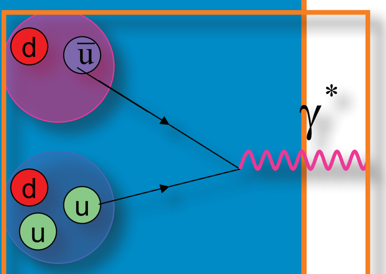
In 2008 a second beam test was performed, also with an open configu-ration ofthe spectrometer, a π^- beam of 190 GeV/c, and a polyethylene target

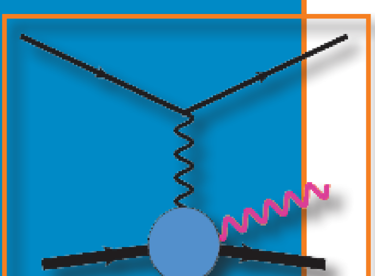
- The target temperature does not seem to increase signifcantly with the hadron beam, long polarization relaxation times measured (2007 beam test)
- Reasonable occupancies in the detectors closer to the target can only be achieved if a hadron absorber and beam plug is used (2008 beam test)
- Physics simulation were validated, within statistical errors (J/ψ peak and combinatorial background, in 2007 and 2009 beam tests)

Beam test 2009

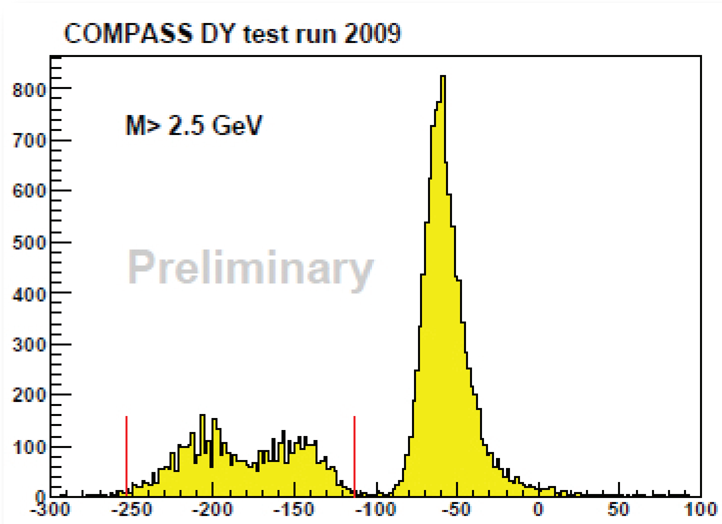


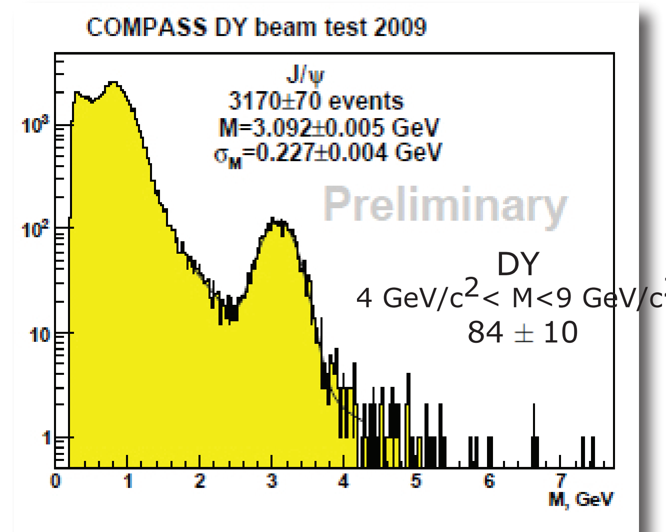






π^- beam of 160 GeV/c on 2-cells polyethylene target. Setup including hadron absorber and a beam plug (3 days of data-taking)





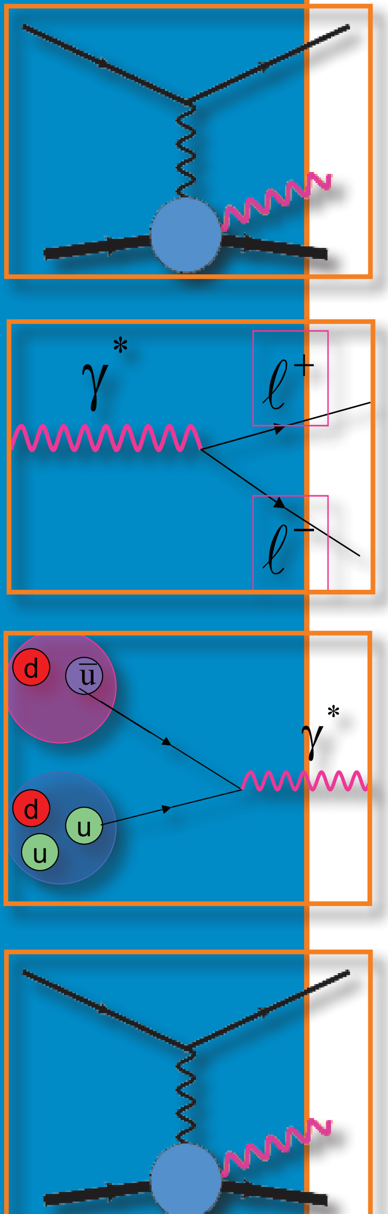
Reasonable Zvertex separation, allowing to distinguish the 2 target cells and the absorber

Data taken without the optimised dimuon trigger with target pointing capability

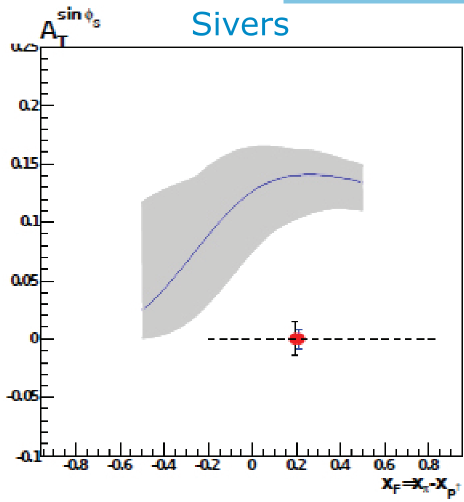
The expected number of J/Ψ and DY events from Monte-Carlo was confirmed:
expected J/Ψ: 3600 ± 600
expected DY events (4 GeV/c^2< M<9 GeV/c^2): 110 ± 22

Combinatorial background (from uncorrelated π decays) is estimated using the measured like-sign $\mu^{\pm}\mu^{\pm}$ distributions:
the absorber reduces the background by a factor 10 at $M_{\mu\mu}$ = 2 GeV/c^2

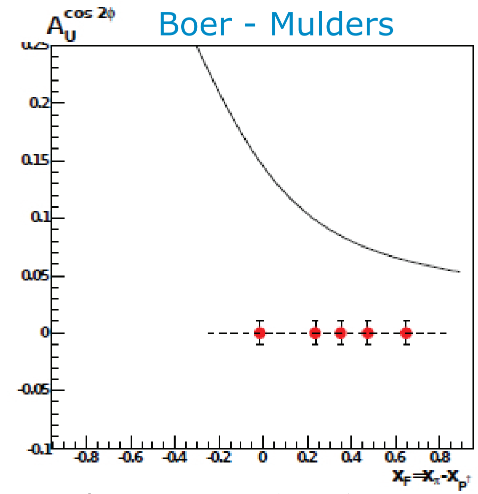
Asymmetries @COMPASS-II: comparing with theory prediction



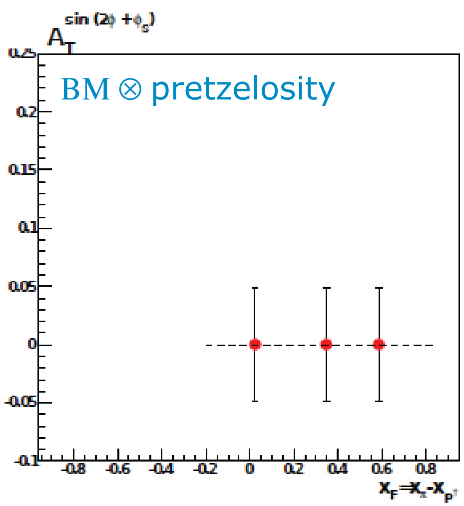
2 years of data taking
DY 4.-9. GeV/c²

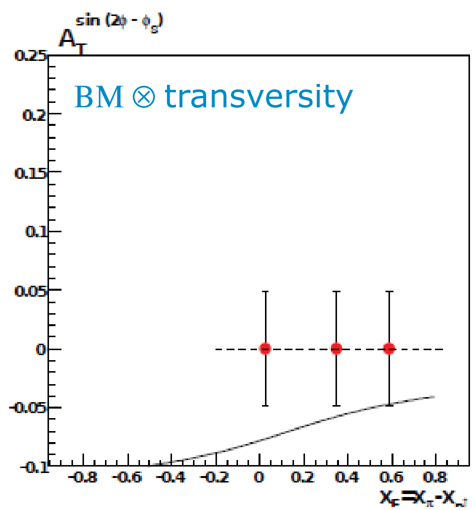


M. Anselmino et al., in Proceedings of Transversity 2008, 2009, ISBN:978-981-4277-77-8, p. 138



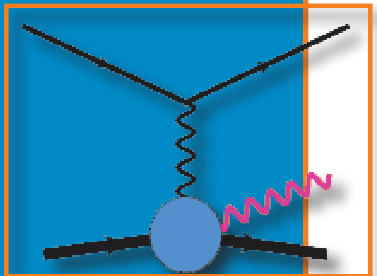
D. Boer, Phys. Rev. D60 (1999) 014012.
B. Zhang et al., Phys. Rev. D77 (2008) 054011.

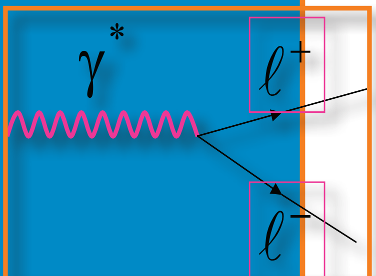


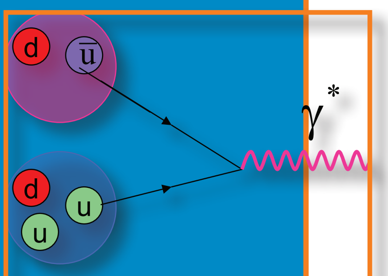


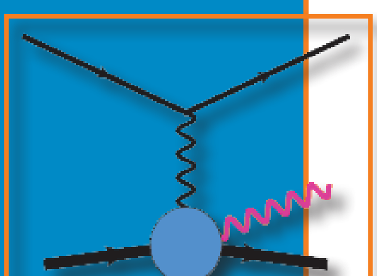
V. Barone et al., Phys. Rept. 359 (2002) 1.
V. Barone et al., Phys. Rev. D56 (1997) 527.

COMPASS-II DY setup: new hardware developments





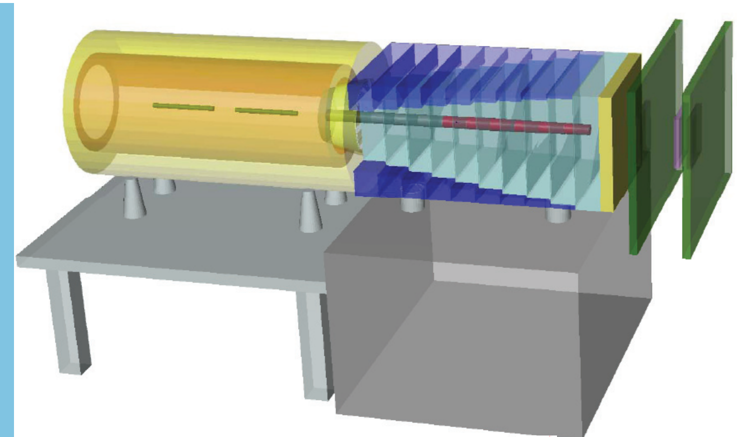


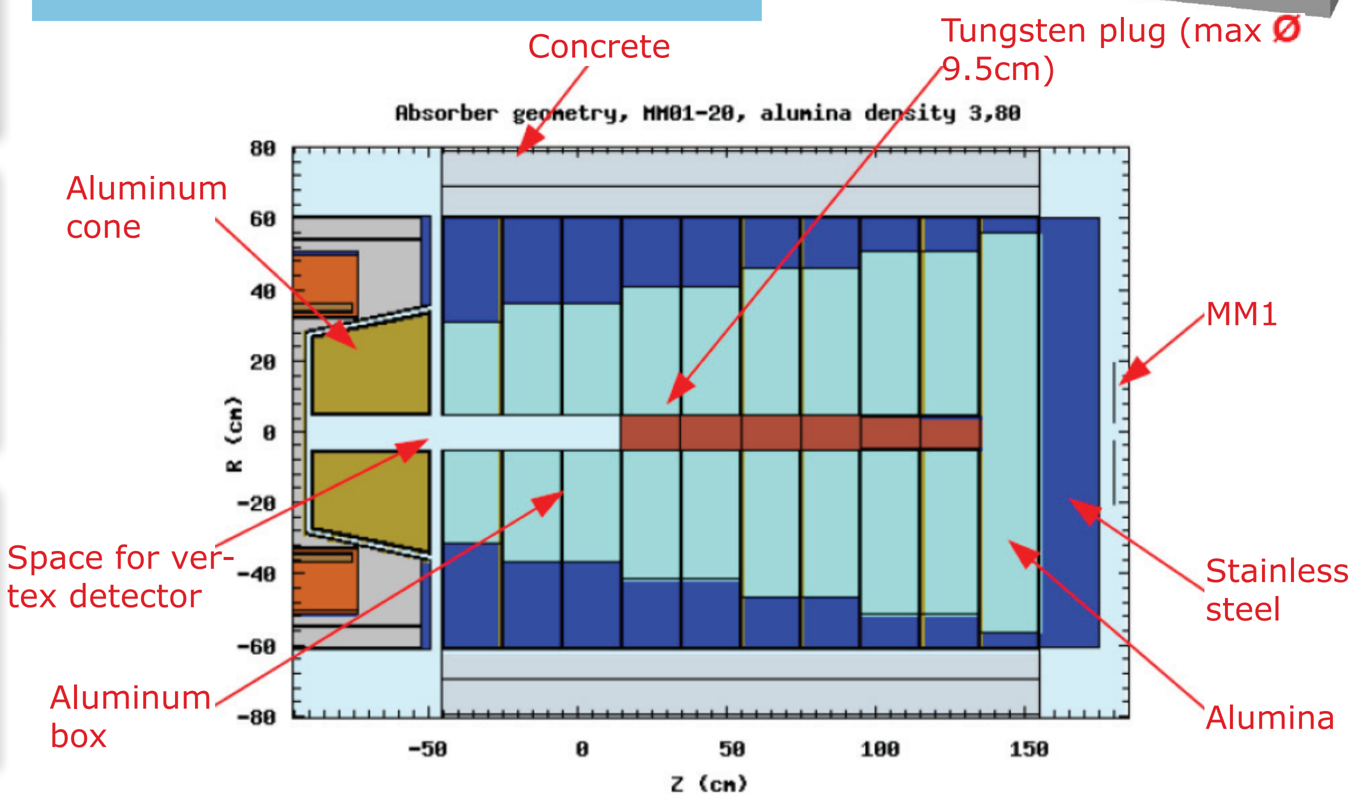


Two target cells (NH_3) inside the dipole (55 cm length, 4 cm diameter, spaced by 20 cm)

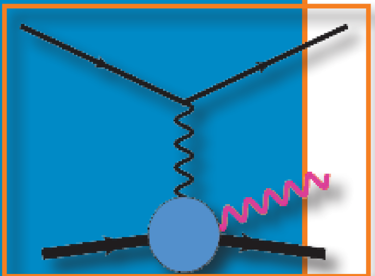
The absorber is 236 cm long, made of Al_2O_3

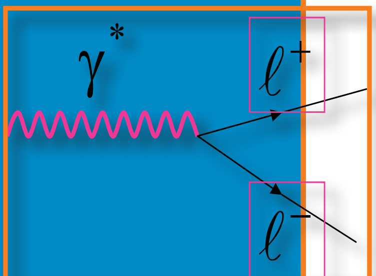
The plug is made of 6 discs of W 20 cm long each and 20 cm of Alumina in the most downstream part (total of 140 cm)

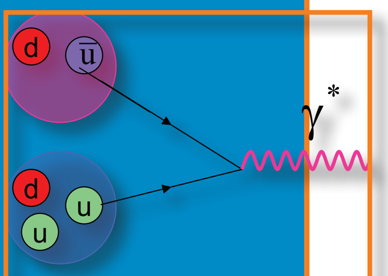


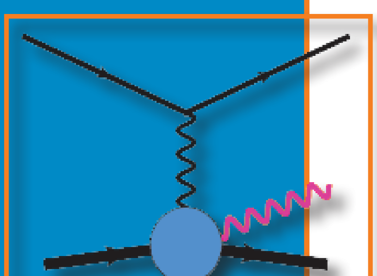


COMPASS-II: Summary









COMPASS-II has been recommended by SPSC and is approved by the Research Board

2012 Primakoff run with π , k beam --> test of chiral perturbation theory

+

pilot run of DVCS with μ^+ and μ^- beams on unpolarised protons --> t-slope (one mean value of B in x_B) and transverse size of the nucleon

2013 CERN SPS shut down (change over to Drell-Yan setup)

2014 Single polarised Drell-Yan with π^- beam --> TMDs (Sivers and Boer-Mulders) sign change

2015+16 DVCS with μ^+ and μ^- beams on unpolarised protons
--> constrain GPD H, t-slope parameter B
In addition complementary information through HEMP

in parallel unpolarised SIDIS --> PDFs, TMDs, FFs (in particular for strange)

beyond 2016?

...Second year of Drell-Yan data taking --> TMDs (Sivers, Boer-Mulders, and Pretzelosity), transversity PDF

...DVCS & HEMP with μ^+ and μ^- beams on transversely polarised protons --> constrain GPD E

...Further spectroscopy measurements