Forthcoming Drell-Yan measurements at COMPASS

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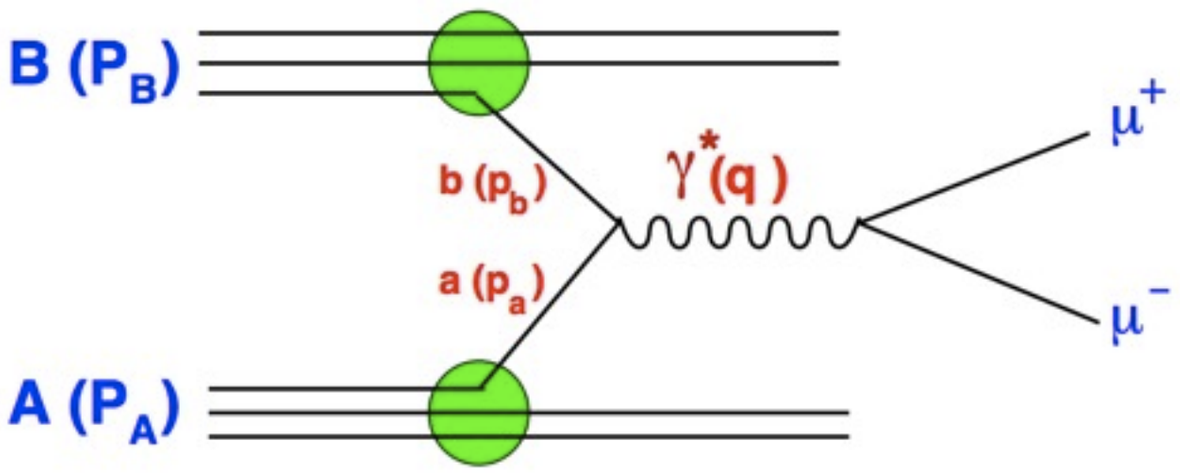
on behalf of the COMPASS collaboration

DSPIN-2011

Drell-Yan process



$$p_a = \sqrt{s}/2\; x_a(1,0,1)$$

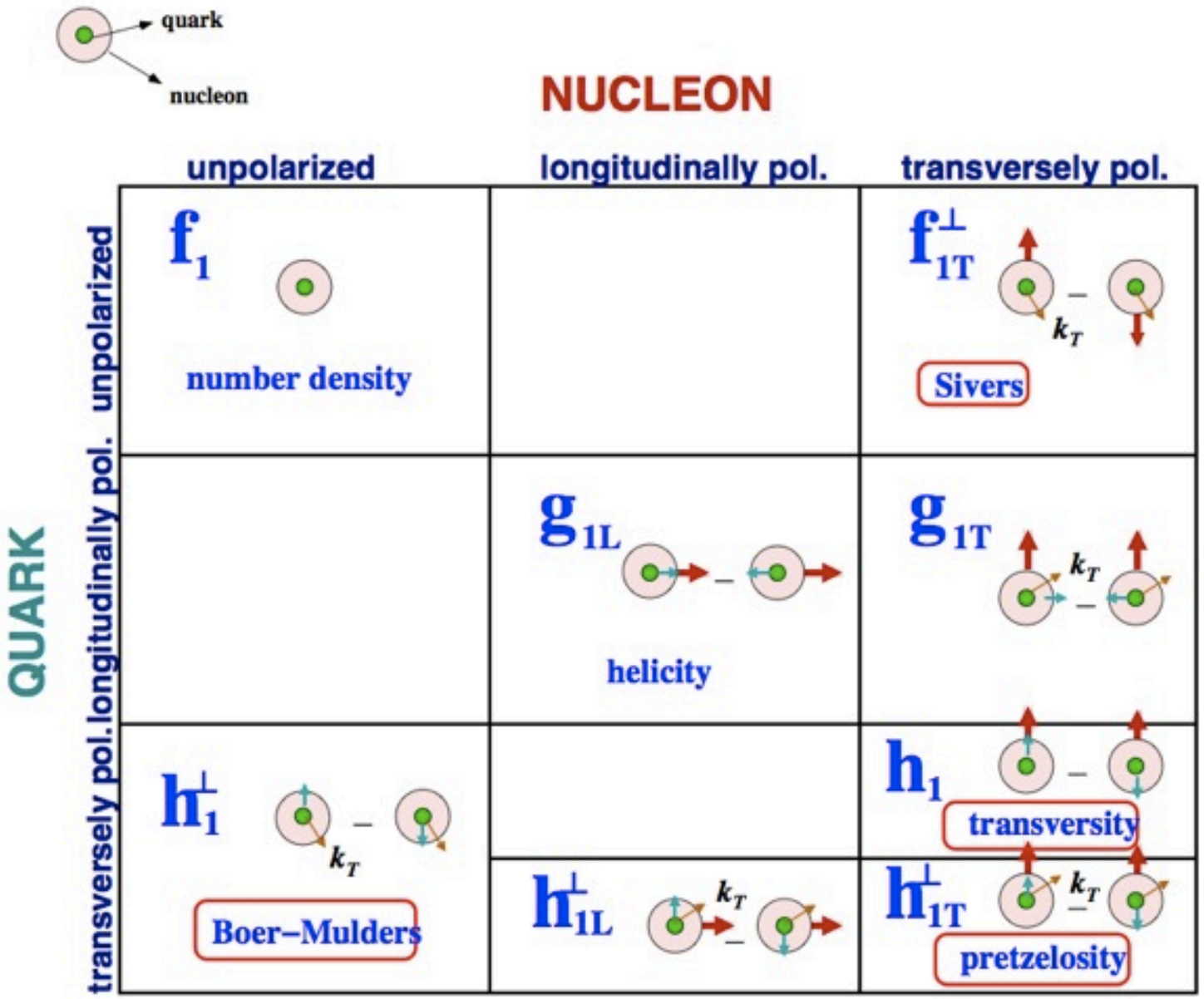
$$p_b = \sqrt{s}/2\; x_b(1,0,-1)$$

$$q = p_a + p_b = (q_0, 0, q_L)$$

$$\frac{d\sigma}{dQ^2} = \sum_{q=u,d,s} \int dx_a \int dx_b \; (q(x_a)\bar{q}(x_b) + \bar{q}(x_a)q(x_b))\; \hat{\sigma_0}\; \delta(Q^2 - \hat{s})$$

Drell-Yan cross section includes a convolution of parton distribution functions

Nucleon structure and PDFs



3 PDFs are needed to describe nucleon structure in collinear approximation

8 PDFs are needed if we want to take into account intrinsic transverse momentum k_T of quarks

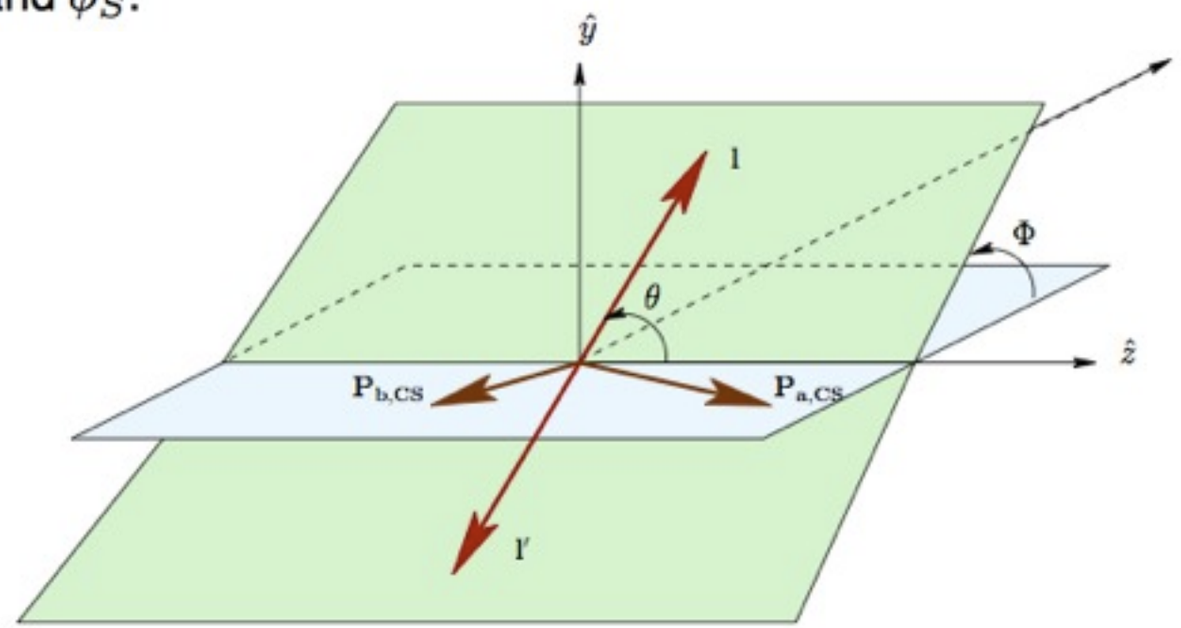
Drell-Yan cross section

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

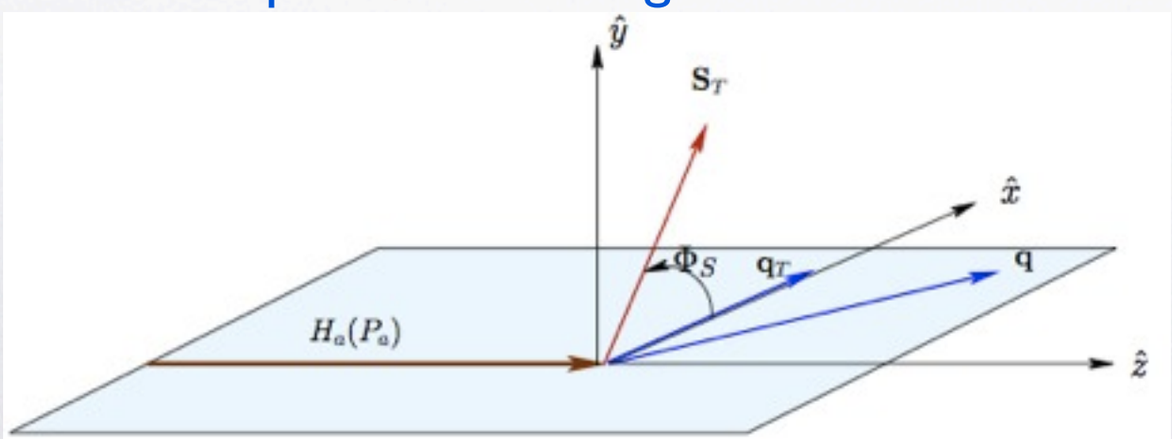
Single polarized DY

- A: azimuthal asymmetries – $A_U^{\cos 2\phi}$, $A_T^{\sin\phi_S}$, $A_T^{\sin(2\phi+\phi_S)}$ and $A_T^{\sin(2\phi-\phi_S)}$
- D: depolarization factor
- S: target spin components
- $F = 4\sqrt{(P_a \cdot P_b)^2 - M_a^2 M_b^2}$
- $\hat{\sigma}_U$: part of the cross-section surviving integration over ϕ and ϕ_S.

Definition of angles ϕ and θ of the lepton momenta in the Collins-Soper frame



Definition of azimuthal angle ϕ_S of transverse target spin S_T in the target rest frame



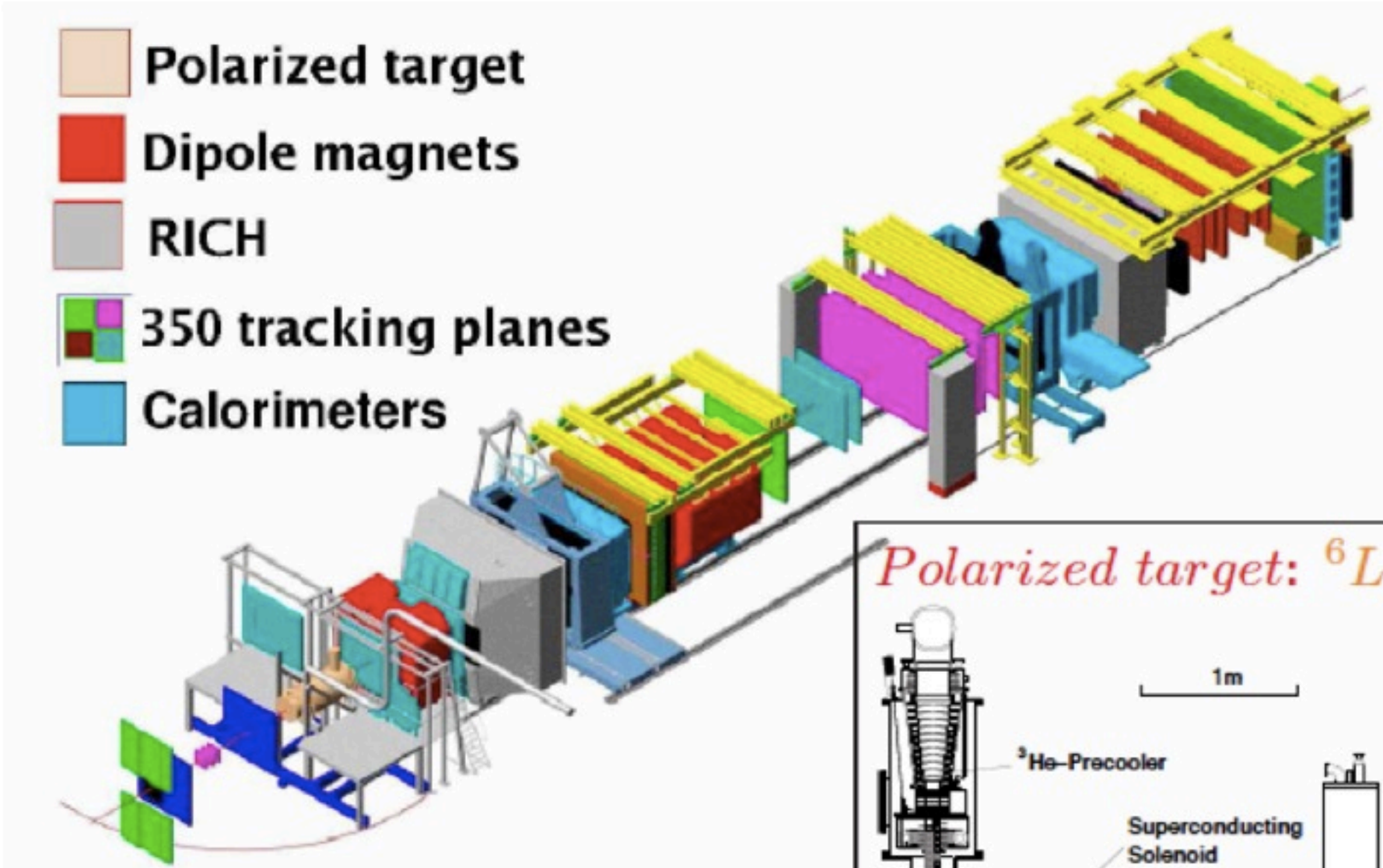
Drell-Yan cross section

Each asymmetry contains a convolution of 2 PDFs, one from target and another from beam quarks.

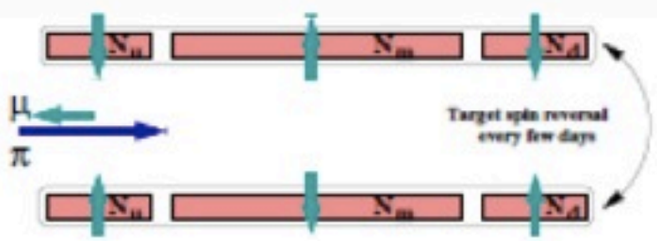
- $A_U^{\cos 2\phi}$: access to Boer-Mulders functions of incoming hadrons;
- $A_T^{\sin \phi_S}$: access to the Sivers function of target nucleon;
- $A_T^{\sin(2\phi+\phi_S)}$: access to Boer-Mulders function of beam hadron and to pretzelosity of target nucleon;
- $A_T^{\sin(2\phi-\phi_S)}$: access to Boer-Mulders function of beam hadron and to transversity of the target nucleon.

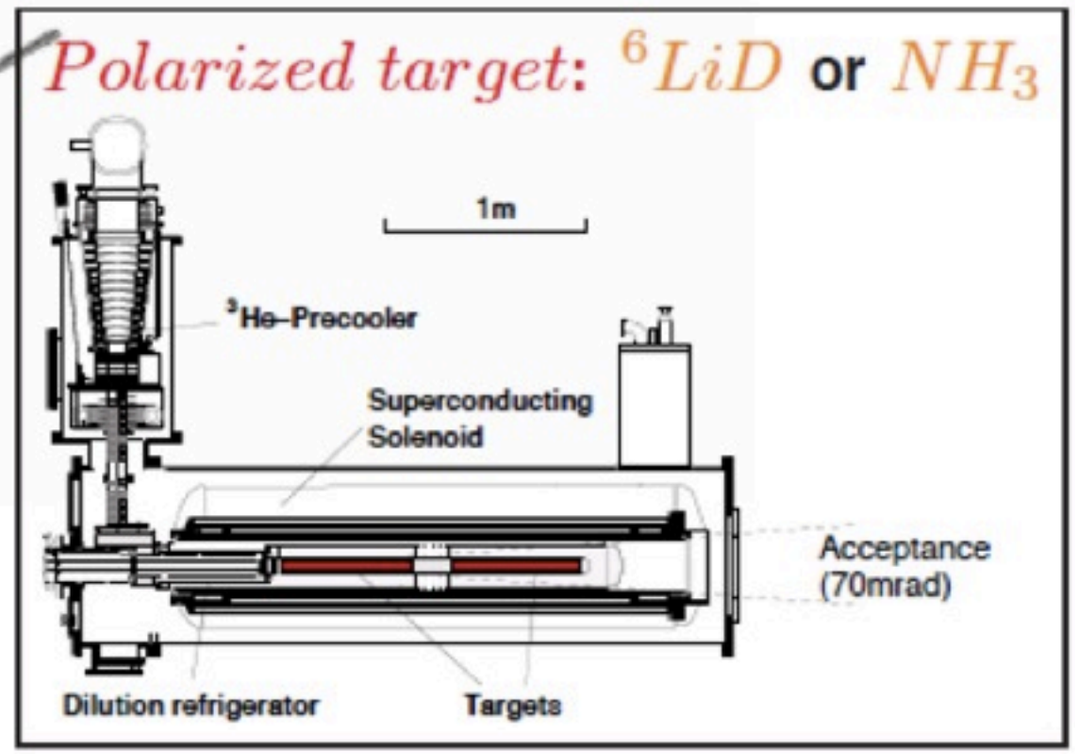
All these asymmetries are expected to be sizable in the valence quarks range and can be measured at COMPASS

The COMPASS experiment at CERN



μ or π beam





COMPASS-II future program

Long-term plans for at least 5 years starting since 2012

- Tests of chiral perturbation theory via Primakoff processes (measurements with pion/kaon beam and thin nuclear targets)
- Study of deeply virtual Compton scattering (DVCS) and deeply virtual meson production (DVMP) with muon beam and unpolarized LH_2 target in order to constrain GPD H Parallel measurement of unpolarized PDFs and TMD effects in SIDIS
- Measurements of Drell-Yan cross section with pion beam and transverse polarized NH_3 target in order to access transverse momentum dependent PDFs

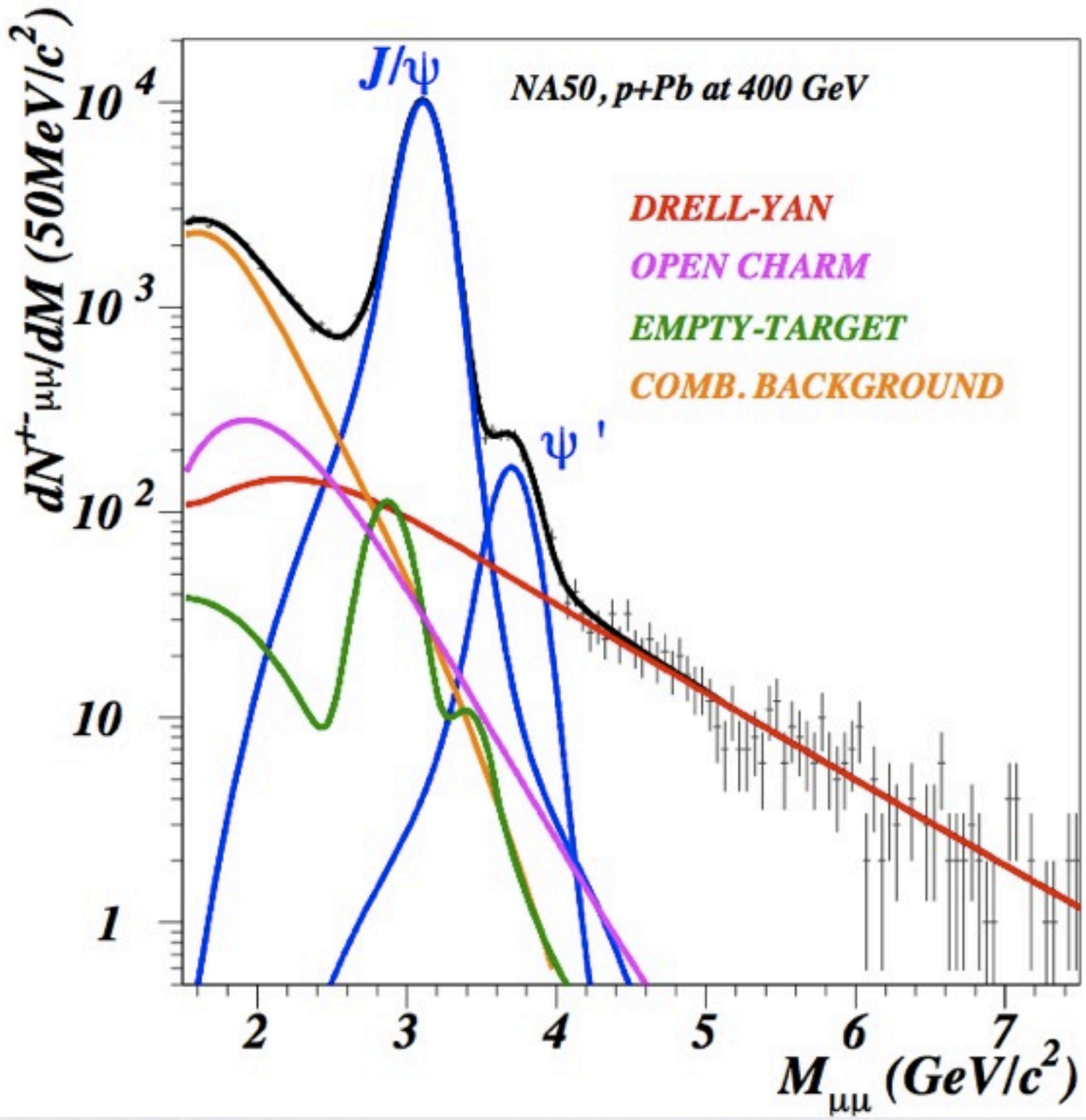
COMPASS setup for Drell-Yan measurements

- Transverse polarized NH_3 target (2 cells)
- π^- beam of 190 GeV/c (up to 10^8 π/s)
- High luminosity ($L=10^{32}$ cm^{-2} s^{-1})
- Beam dump

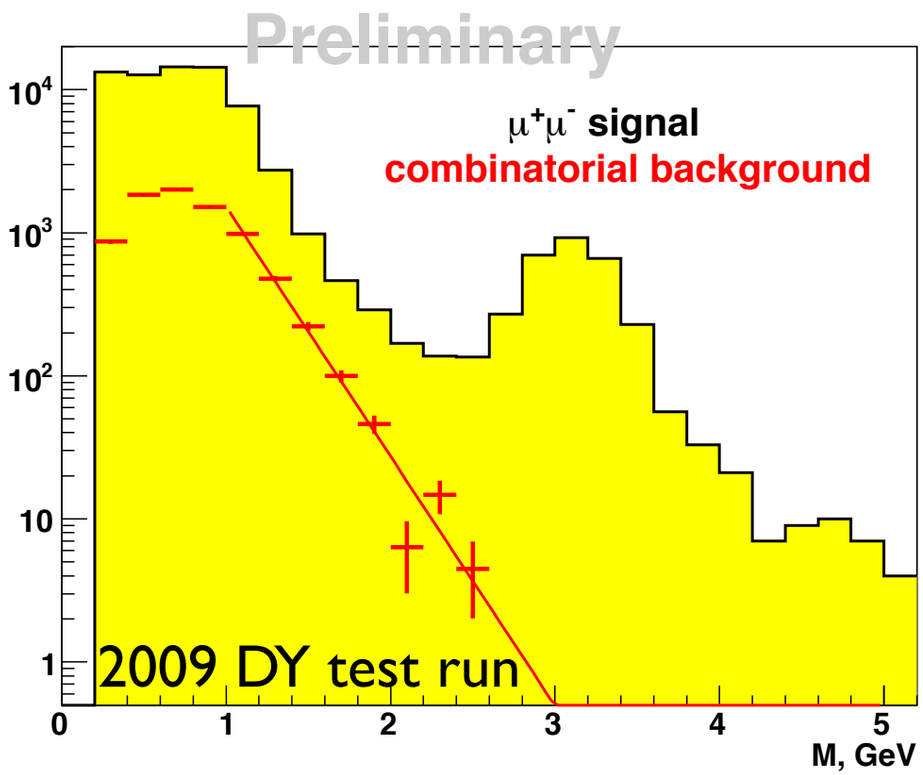
- J/ψ peak as monitoring signal
- Expected rate of Drell-Yan events:

2 GeV<M<2.5 GeV: ~5 000 events/day
4 GeV<M<9 GeV: ~800 events/day

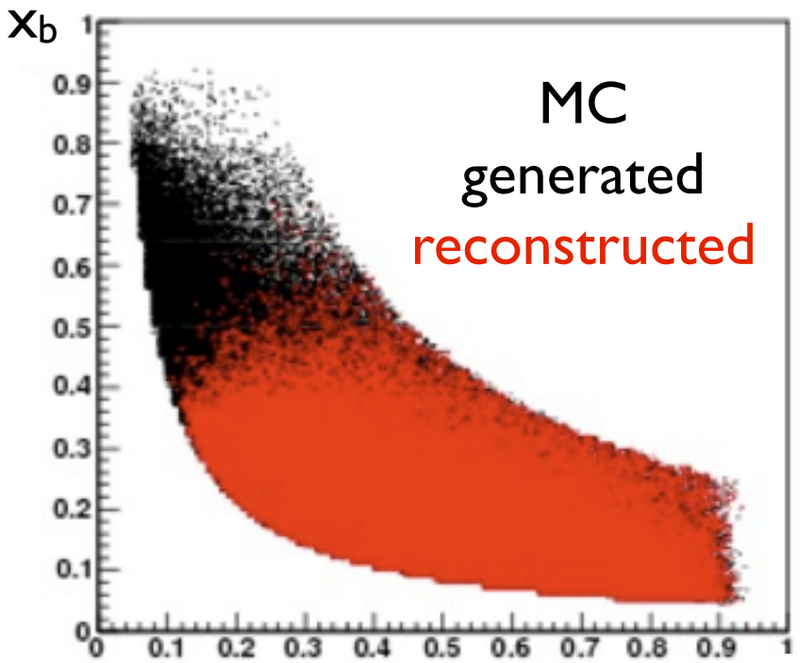
Kinematic range for DY studies

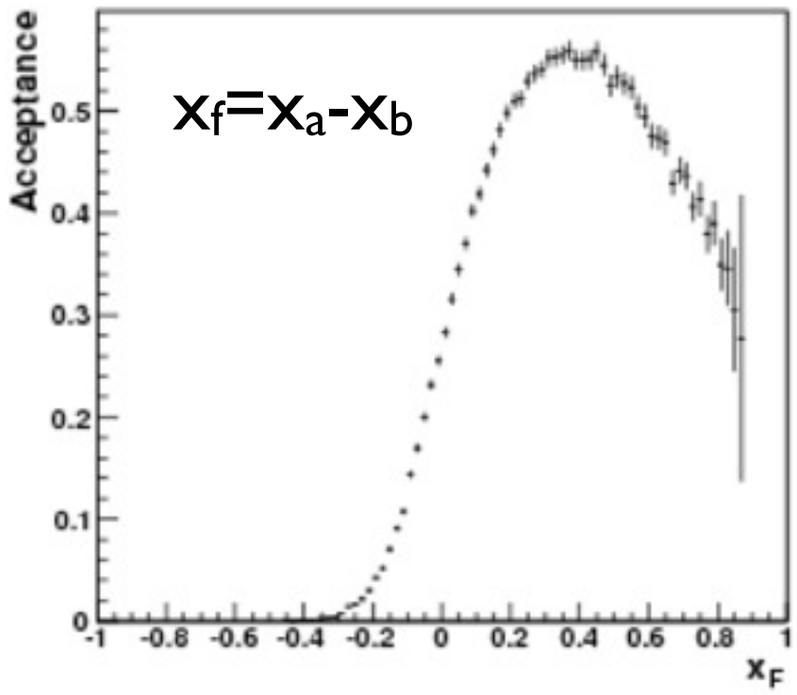


Safe range for Drell-Yan studies : 4-9 GeV



COMPASS kinematic range



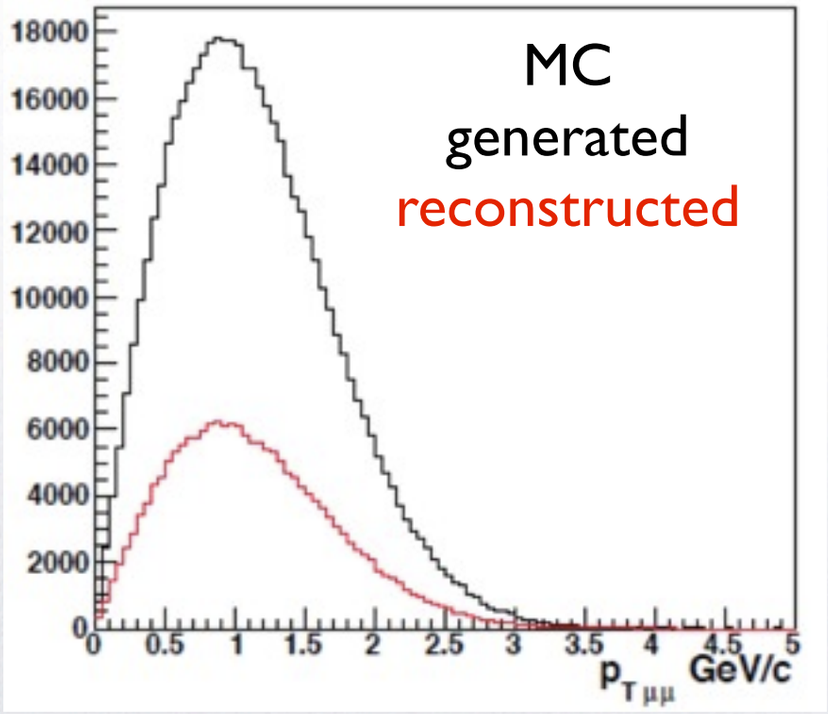


pion

$$x_a = \frac{Q^2}{P_\pi q}$$

proton

$$x_b = \frac{Q^2}{P_p q}$$



COMPASS is at:

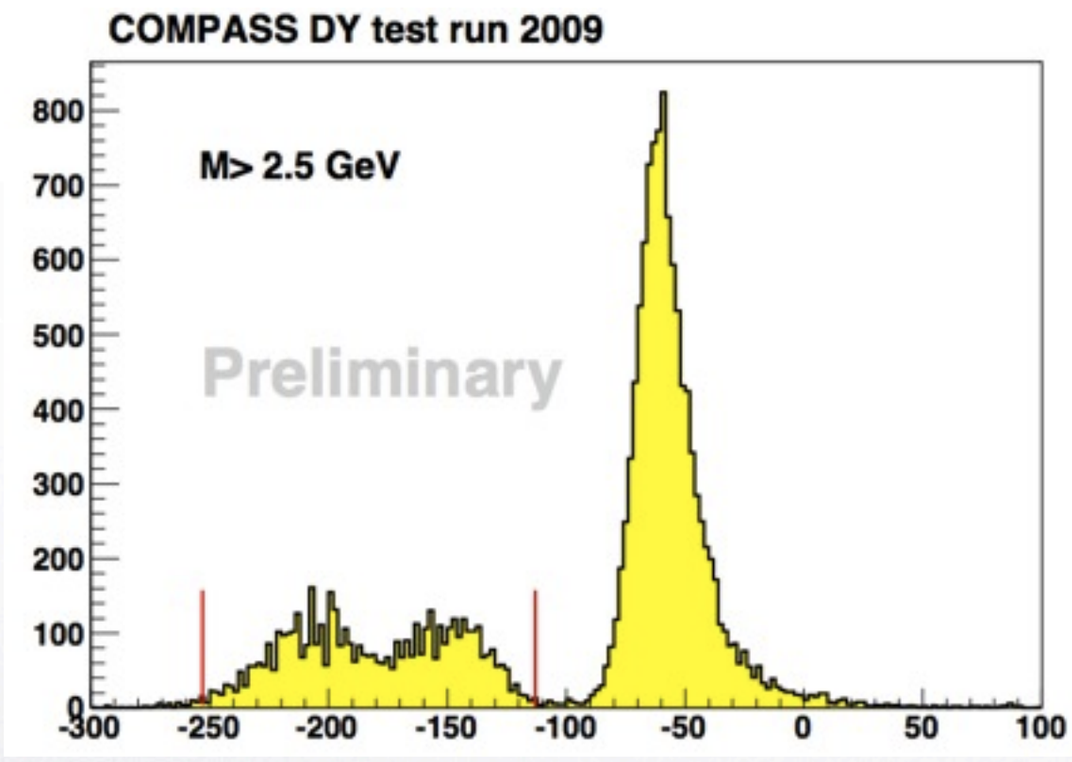
1) valence range ($x \gtrsim 0.1$) for both quarks (so we deal with pure u-ubar annihilation)

2) $x_f > 0$

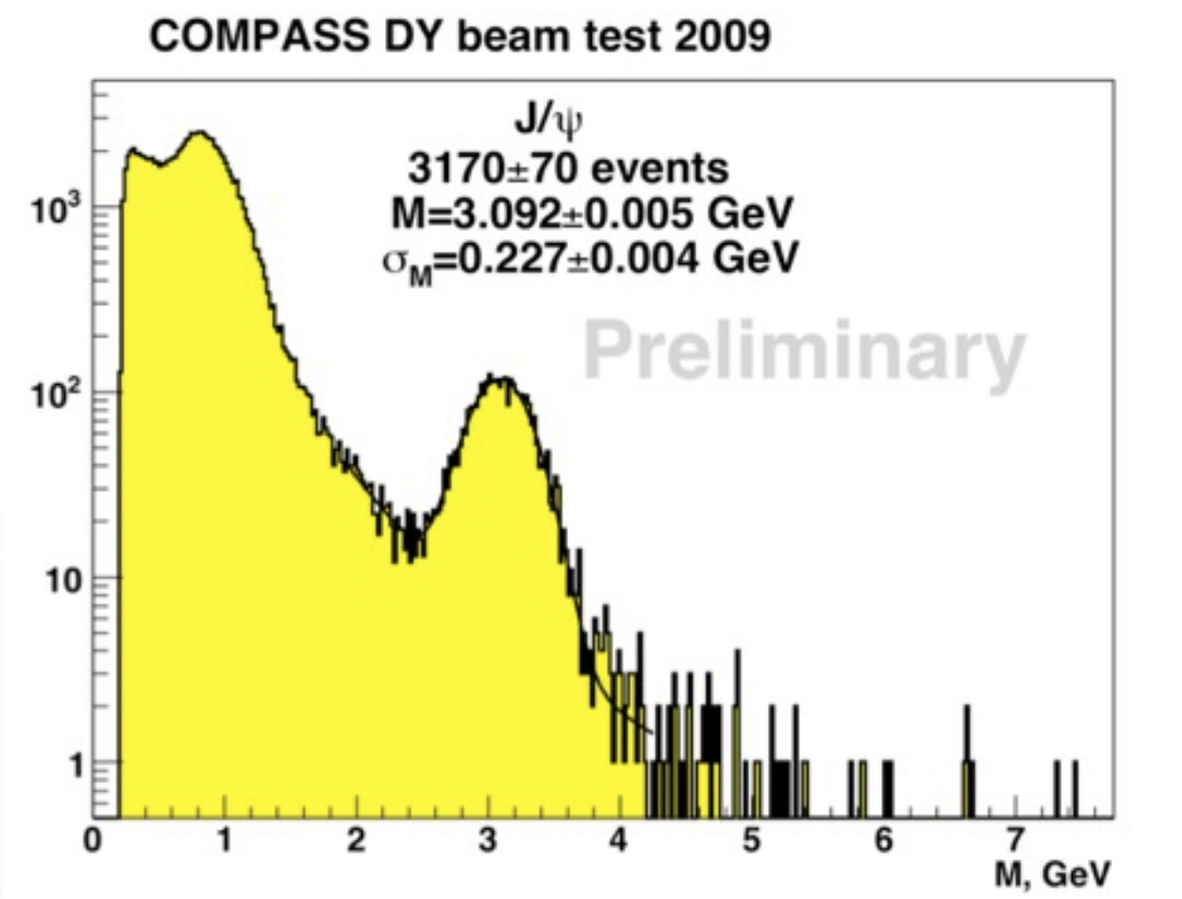
3) $P_{T\ \text{dimuon}}$ about 1 GeV/c where TMD effects are dominant

DY test run at COMPASS (2009)

Beam intensity : 8×10^7 π^- per spill
Two CH_2 target cells (40+40 cm)
Hadron absorber



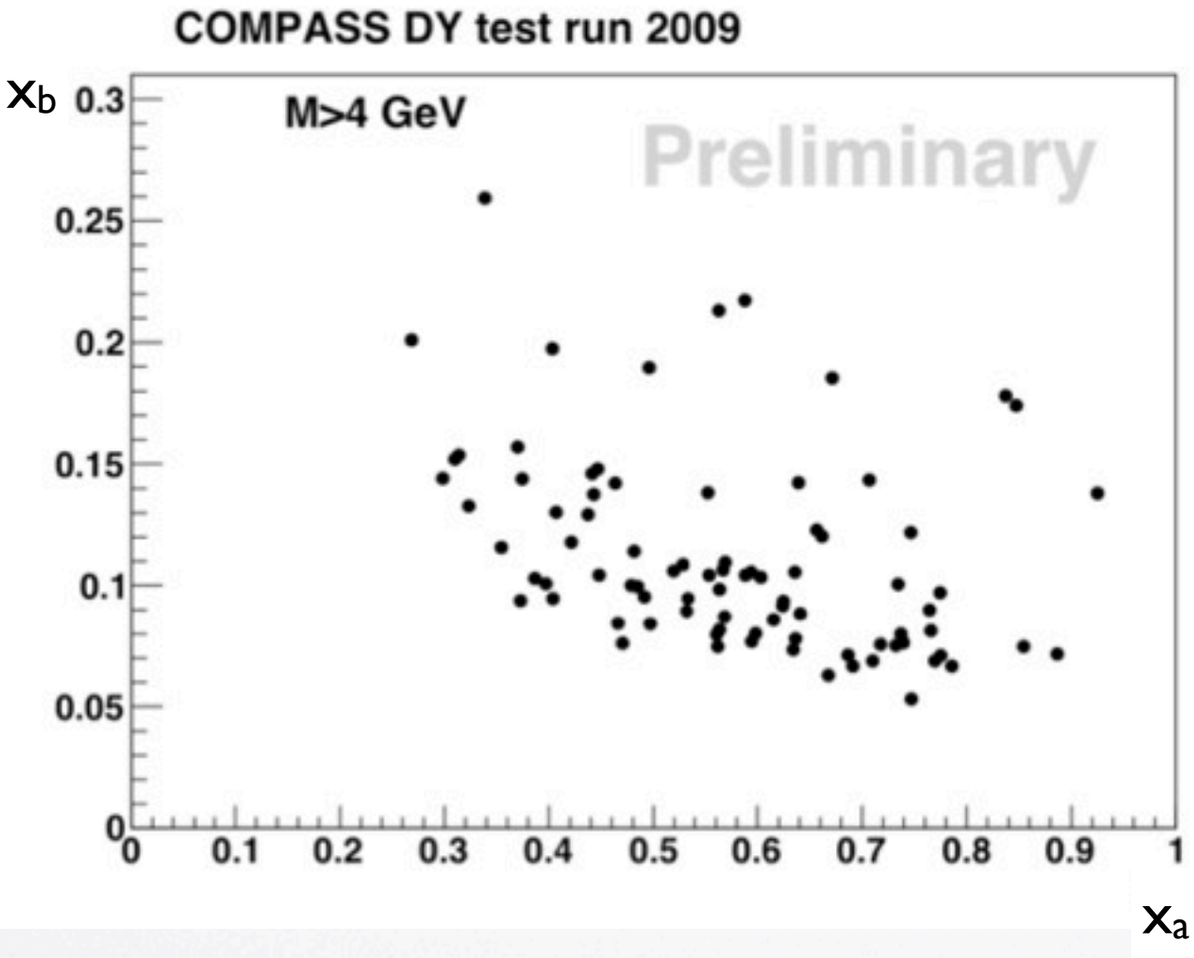
Reconstructed z-vertex position: two target cells and absorber are visible

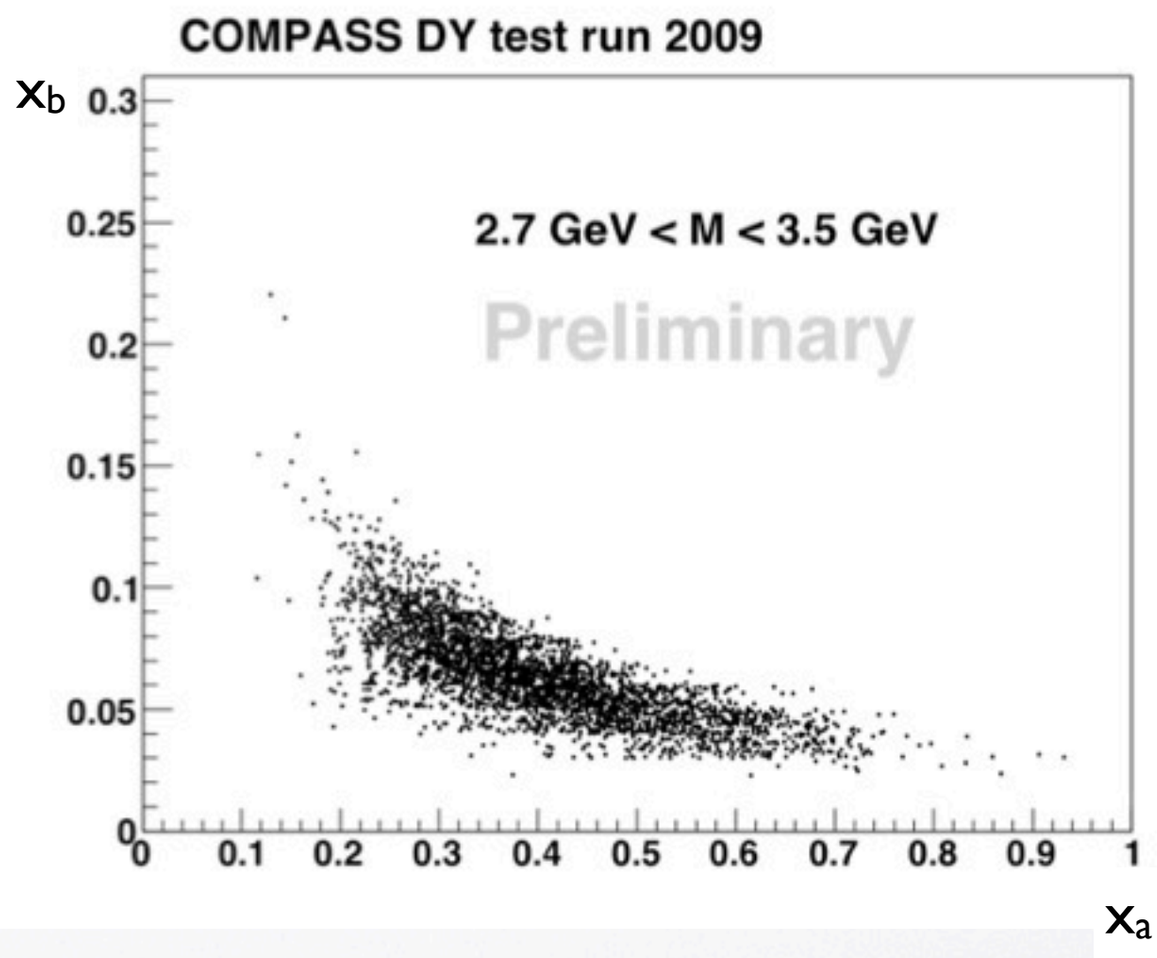


Mass spectrum of dimuons

	Expected	Found
J/ψ	3600±600	3170±70
DY M>4 GeV	110±22	84±10

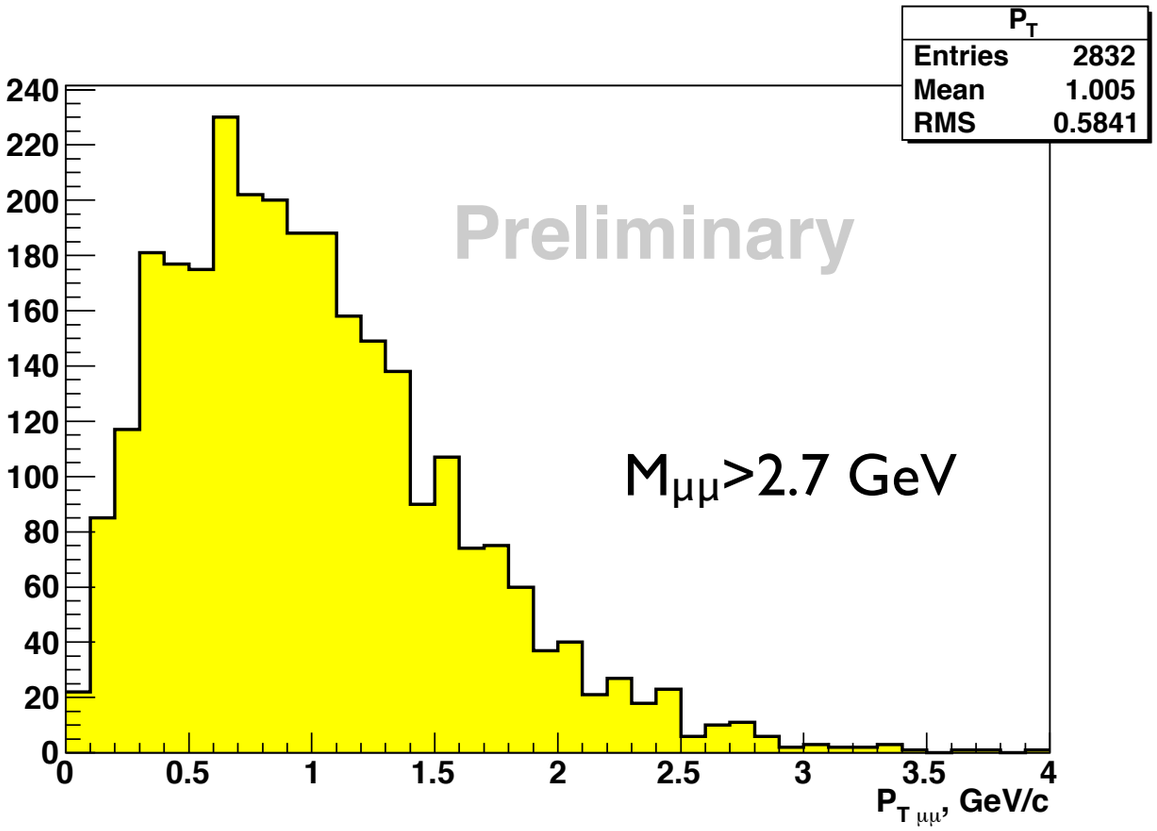
Kinematic plots for x_a and x_b

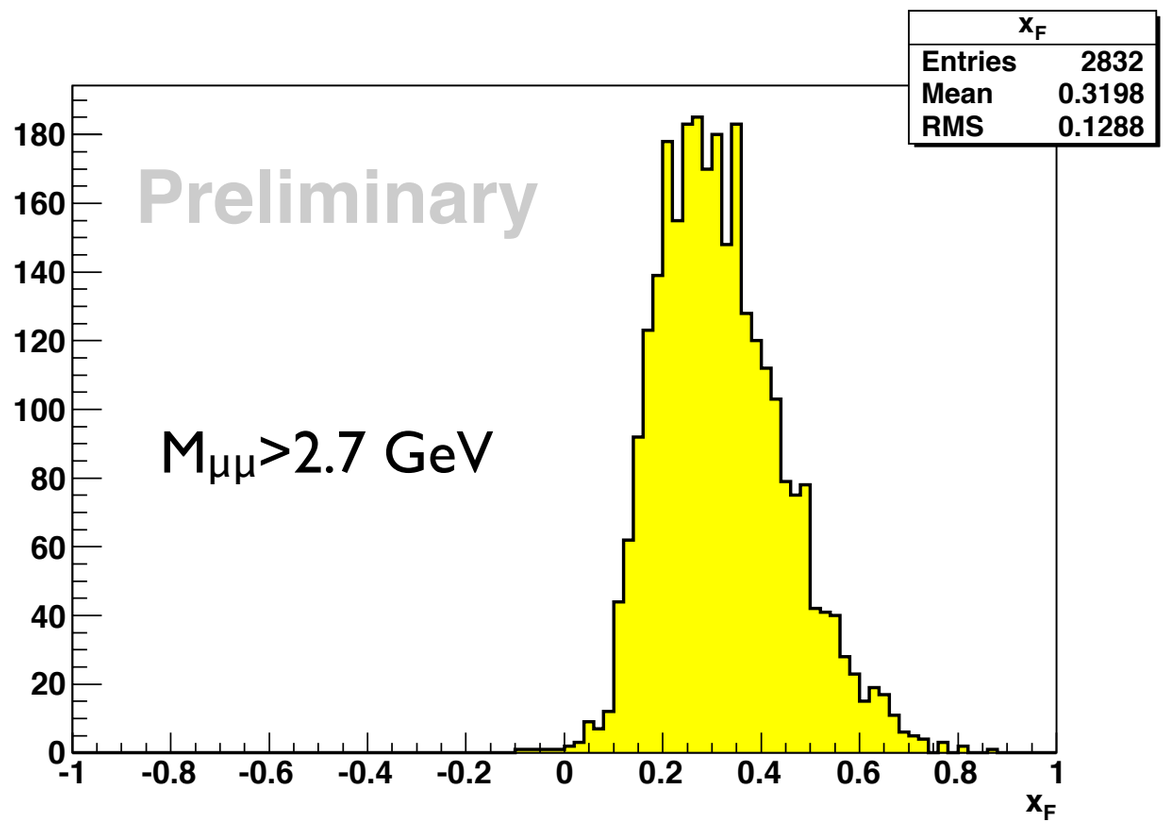




COMPASS acceptance covers the range of valence quarks for both DY and J/ψ

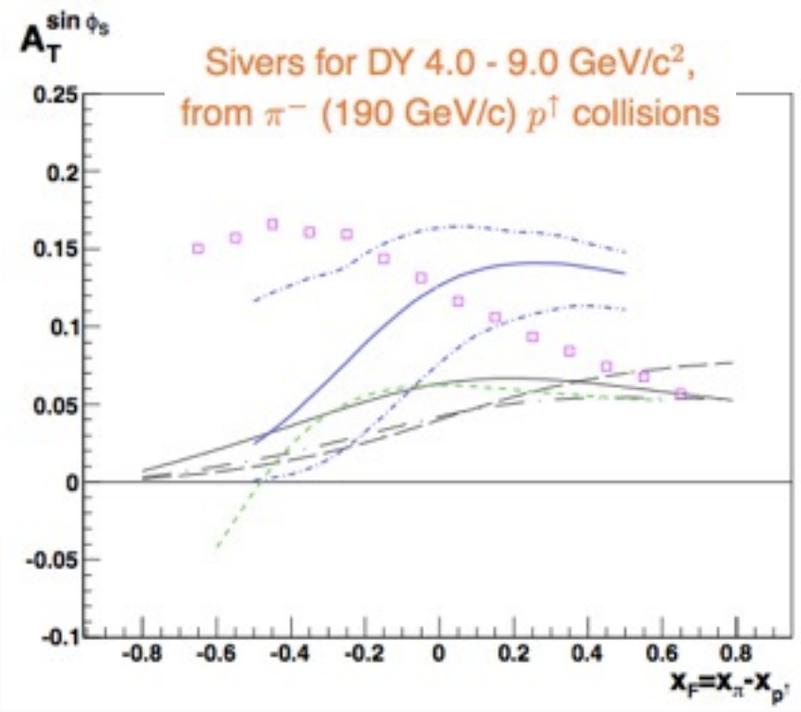
Kinematic plots for p_t and x_f

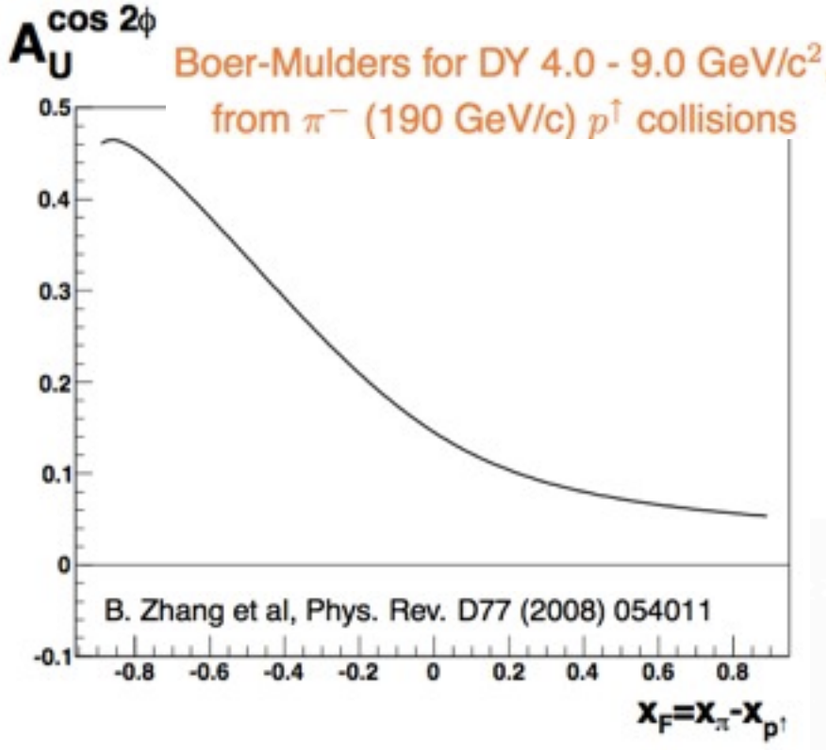


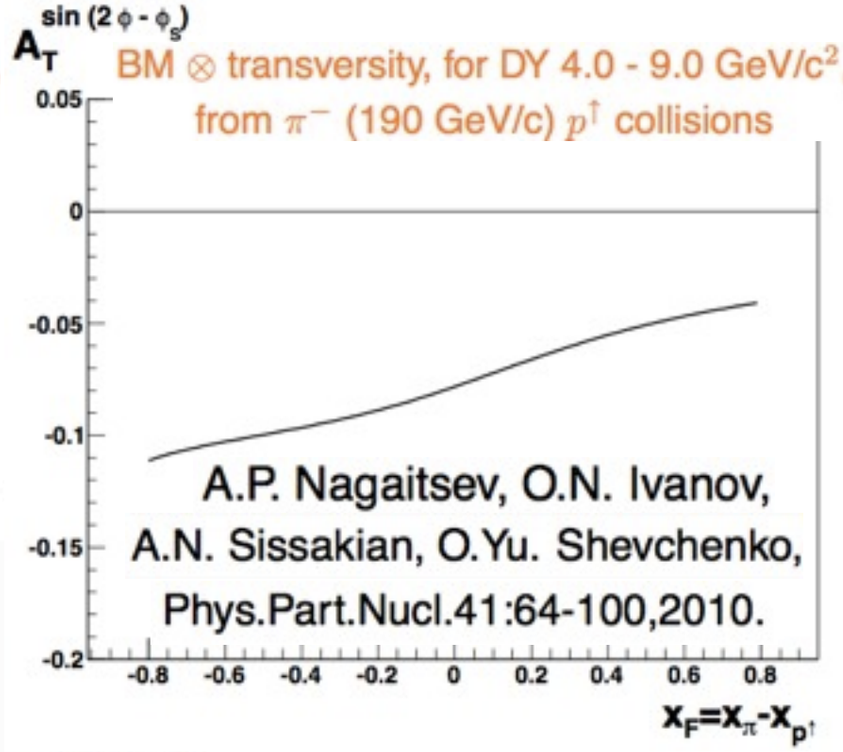


Kinematic distributions for **x_f** and **p_T** of dimuon obtained during Drell-Yan test run 2009 correspond to our expectations

Asymmetries: expectations







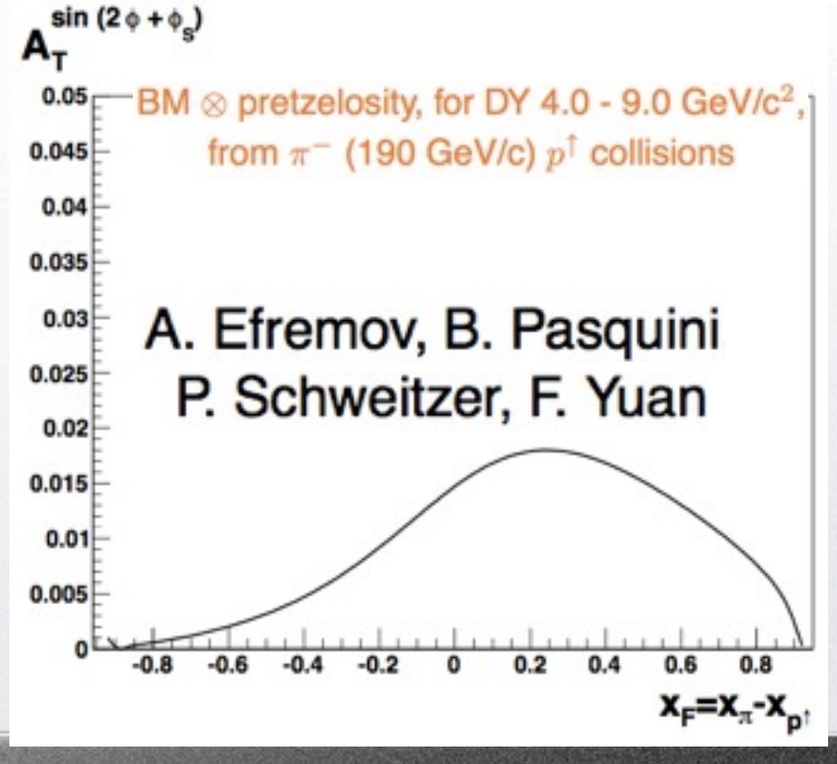
– solid and dashed: Efremov et al, PLB612(2005)233;

– dot-dashed: Collins et al, PRD73(2006)014021;

– solid,dot-dashed: Anselmino et al, PRD79(2009)054010;

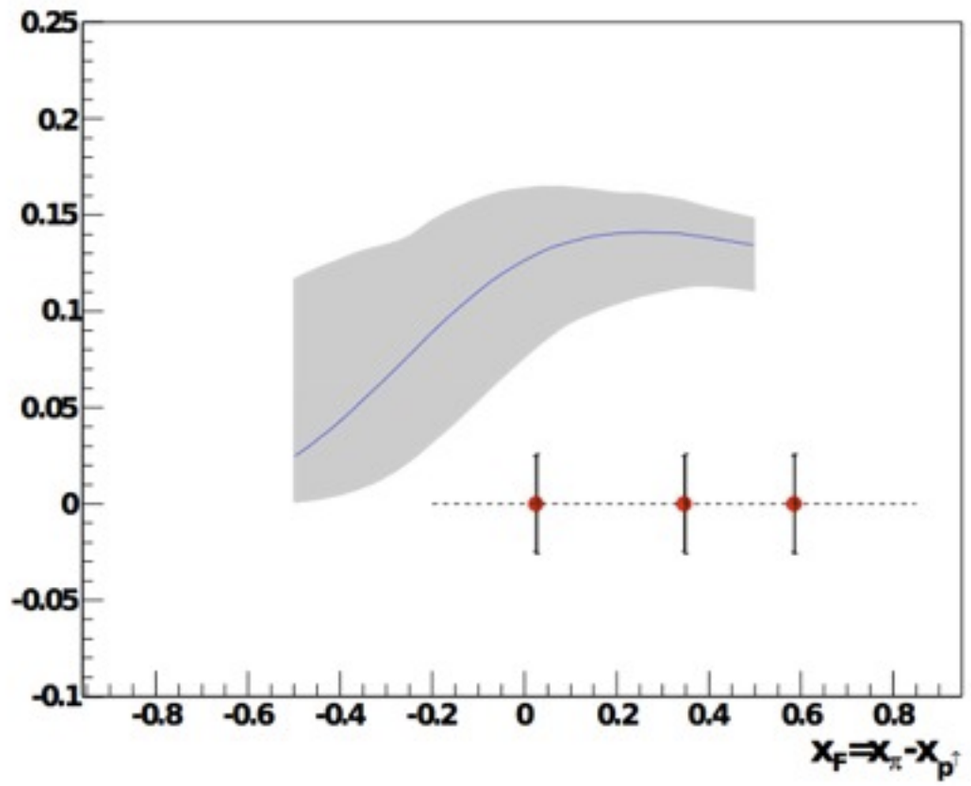
– boxes: Bianconi et al, PRD73(2006)114002;

– short-dashed: Bacchetta et al, PRD78(2008)074010.



Expected accuracy

280 days of data taking with beam intensity 6×10^8 per 10 s spill



4<M<9 GeV

230 000 events

We hope to have enough statistics to subdivide DY sample into a few x_f bins

Expected statistical error for asymmetries:

Asymmetry	Dimuon mass (GeV/c^2)		
	$2 < M_{\mu\mu} < 2.5$	J/ψ region	$4 < M_{\mu\mu} < 9$
$\delta A_U^{\cos 2\phi}$	0.0020	0.0013	0.0045
$\delta A_T^{\sin \phi_S}$	0.0062	0.0040	0.0142
$\delta A_T^{\sin(2\phi+\phi_S)}$	0.0123	0.008	0.0285
$\delta A_T^{\sin(2\phi-\phi_S)}$	0.0123	0.008	0.0285

Drell-Yan vs SIDIS

At COMPASS we have unique opportunity to test QCD prediction for Sivers and Boer-Mulders functions:

$$f_{1T}^{\perp}(x, k_T)\big|_{\mathrm{DY}} = -f_{1T}^{\perp}(x, k_T)\big|_{\mathrm{SIDIS}}$$

$$h_1^{\perp}(x, k_T)\big|_{\mathrm{DY}} = -h_1^{\perp}(x, k_T)\big|_{\mathrm{SIDIS}}$$

Sivers function was already measured at COMPASS and the result is compatible with HERMES result

DY and SIDIS measurements will be performed at the same experimental setup and polarized target and in the same kinematic range of Q^2 and x_p

Study of J/ψ production mechanism

$$\sigma_{J/\psi} \approx 30 \times \sigma_{DY>4\ GeV}$$

- Determination of q-qbar and g-g contributions
- J/ψ-DY duality test

$$\sigma\Big|_{H_aH_b\to J/\psi X\to l^+l^-X} = \sigma_{q\bar{q}} + \sigma_{gg}$$

COMPASS vs AnDY

$\sqrt{s} = 19$ GeV

$\pi^- p^\uparrow$

$\mu^+\mu^-$

higher level
of feasibility studies

$\sqrt{s} = 500$ GeV

$pp^\uparrow$

e^+e^-

Different (but overlapping) kinematic ranges
Different background conditions

COMPLEMENTARY MEASUREMENTS

Summary

- Polarized Drell-Yan measurement is a part of COMPASS-II proposal. This proposal was recommended for approval by CERN SPSC for a first period of 3 years (1 year of Drell-Yan data taking)
- Drell-Yan tests were already performed and suitability of the COMPASS setup for such measurements were demonstrated
- 2 years of data taking will allow to collect enough statistics for test theory predictions and extract TMD PDFs. But even 1 year is enough for Sivers asymmetry measurement with statistical accuracy about 1-2%. Comparison of Sivers and Boer-Mulders functions measured in DY and SIDIS also can be performed.