Polarized Drell-Yan measurement at COMPASS

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On behalf of the COMPASS collaboration

The 7th Circum-Pan-Pacific Symposium
on
High Energy Spin

Outline

- Access PDFs from (polarized) Drell-Yan process
- Experimental setup
  - Spectrometer
  - Polarized target
  - Statistics estimations
- Beam test in 2007 – 2009
- Summary

In the COMPASS experiment

muon program (2002 ~ 2007)

Deeply Inelastic Scattering with polarized muon and polarized nucleon target

Longitudinal polarized target

- gluon spin distribution: ΔG

  See Session-10, K. Klimaszewsk

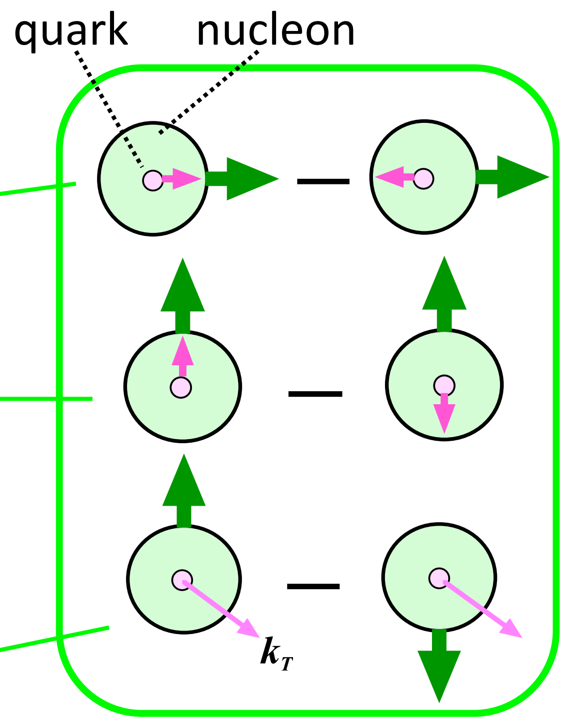
- quark helicity distribution : $\Delta q(x)$

  Since SMC experiment

Transversal polarized target

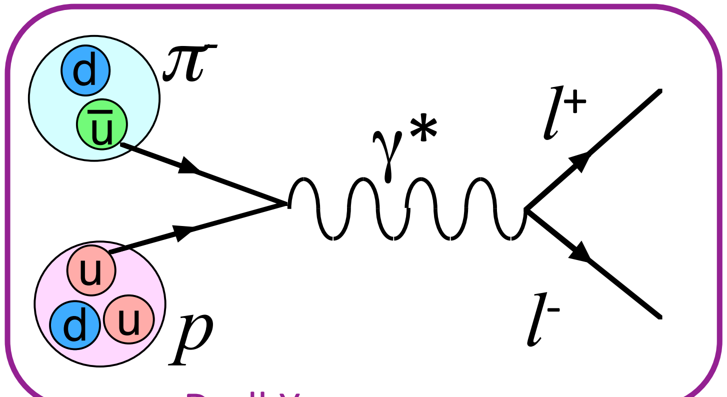
- quark transversity distribution : $\Delta_T q(x)$
- Sivers function : f_{1T}

  Quark orbital angular momentum



Polarized Drell-Yan program (2012 ~)

with pion beam and
transversally polarized target



Drell-Yan process

Motivation - Boer-Mulders function

Unpolarized Drell-Yan

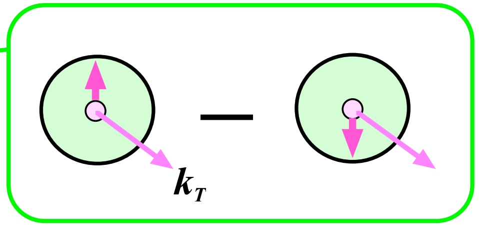
Phys.Lett. B639 (2006) 494

The cos2ϕ angular dependent weighted cross section of (π^-, *p)* at valence region

($x_\pi > 0.1$)

$$\langle W \rangle_{\pi^- p}(x_1, x_2) \propto h_{1\pi}^{\perp(1)}(x_1)\, h_1^{\perp(1),u}(x_2)$$

$h_{1\pi}^{\perp}, \ \overline{h}_{1\pi}^{\perp}$: Boer-Mulders functions of the valence and sea quarks inside the pion respectively



$h_1^{\perp, q(\bar{q})}$: Boer-Mulders functions of the quark flavor inside the proton

The ratio of the weighted cross sections of (π^-, *p)* and (π^-, *D)*

$$\frac{\langle W \rangle_{\pi^- D}(x_1, x_2)}{2\langle W \rangle_{\pi^- p}(x_1, x_2)} = \frac{1}{2}\left(1 + \frac{h_1^{\perp(1),d}(x_2)}{h_1^{\perp(1),u}(x_2)}\right)$$

Flavor separation

Using (π^-, *p) and* (π^+, *p)*

$$\frac{\langle W \rangle_{\pi^+ p}(x_1, x_2)}{2\langle W \rangle_{\pi^- p}(x_1, x_2)} = \frac{1}{4}\frac{h_1^{\perp(1),d}(x_2)}{h_1^{\perp(1),u}(x_2)}$$

Motivation - Transversity and Sivers function

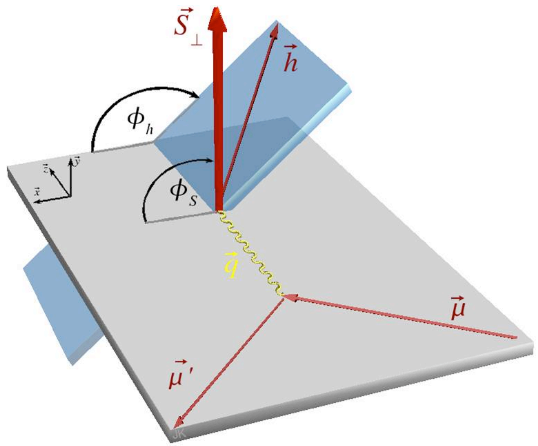
SIDIS many components of transverse target spin dependent azimuthal modulations

(polarized beam with transversal polarized target)

$$A_{Collins}^{\sin(\phi h+\phi s)} \propto \Delta_T q(x)\, H_1(z)$$

$$A_{Sivers}^{\sin(\phi h-\phi s)} \propto f_{1T}^{\perp}(x)\, D_1(z)$$

Uncertainty of Fragmentation Function



Polarized Drell-Yan

(single spin DY asymmetries)

$$A^{\sin(\phi+\phi s2)} \propto h_1^{\perp(1)q}(x_1)\, \Delta_T q(x_2)$$

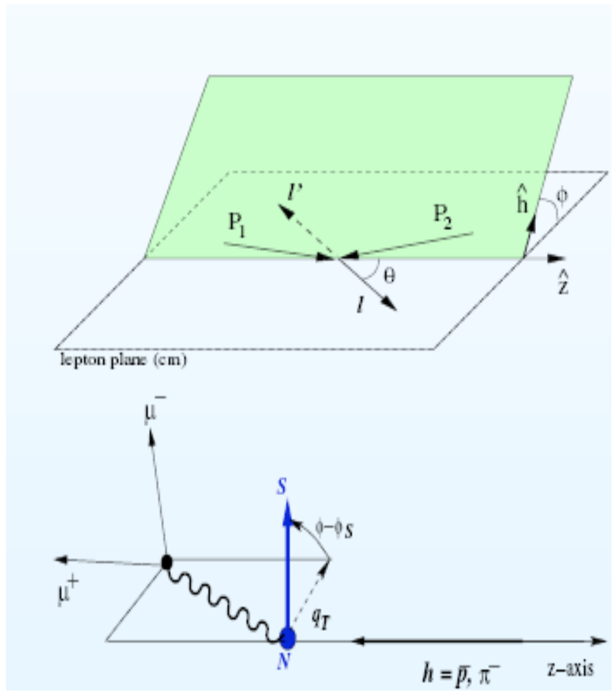
FF free

$$A^{\sin(\phi-\phi s2)} \propto f_1(x_1)\, f_{1T}^{\perp(1)}(x_2)$$

Unpol. PDF

prediction

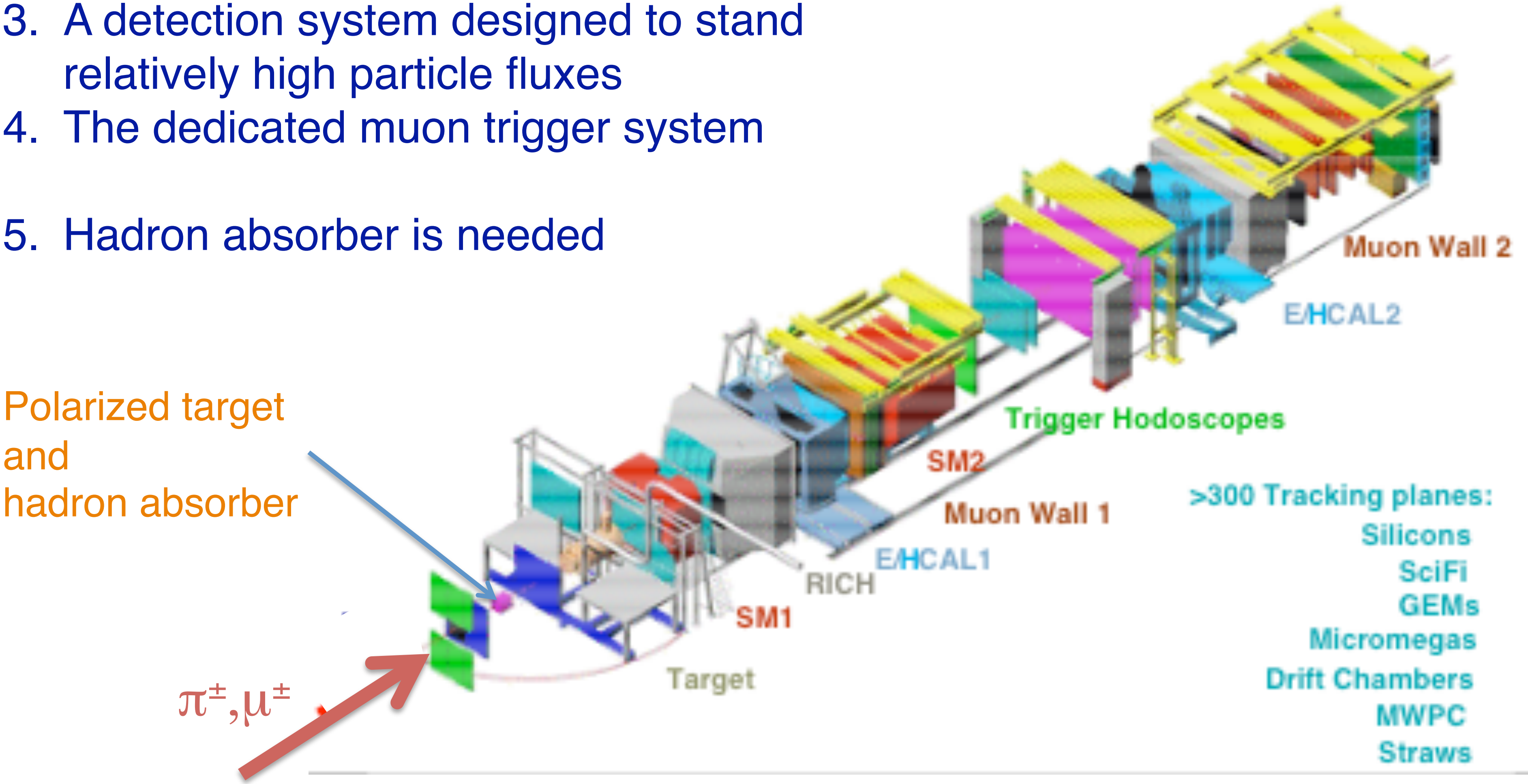
$$f_{1T}^{\perp(1)}\Big|_{DY} = -f_{1T}^{\perp(1)}\Big|_{SIDIS}$$



The COMPASS spectrometer

1. Large angular acceptance spectrometer
2. Various secondary beams with the intensity up to $6x10^7$ particles/s
3. A detection system designed to stand relatively high particle fluxes
4. The dedicated muon trigger system

5. Hadron absorber is needed



COMPASS polarized solid target system

Large acceptance COMPASS Magnet

Transverse polarization

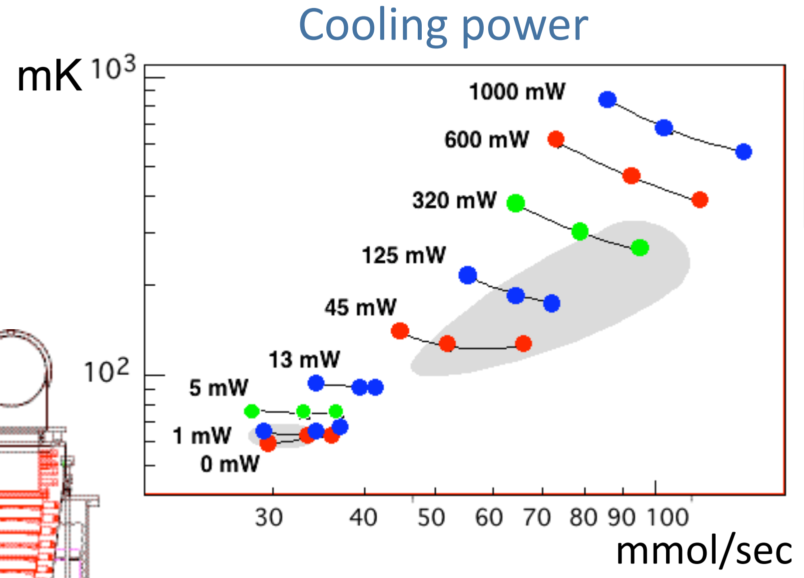
- Frozen spin target at 0.6 T dipole magnet
  (after polarizing at 2.5 T solenoid)

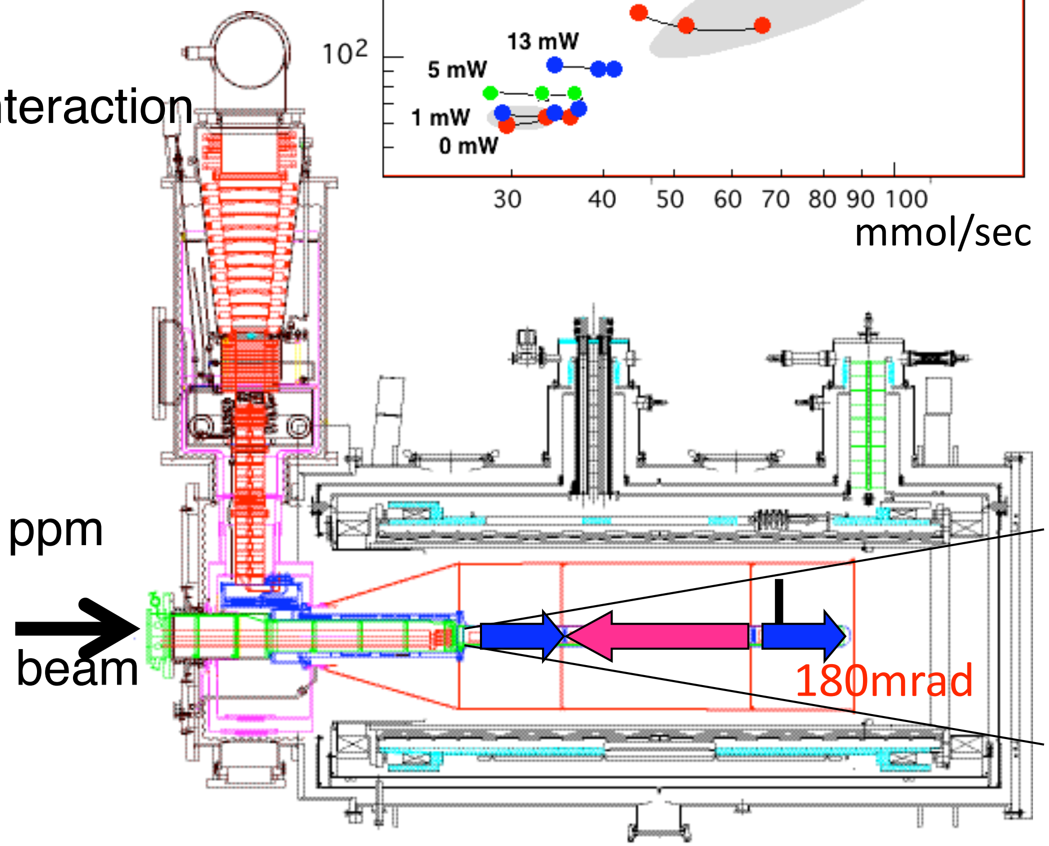
Cooling power

- Many secondly particels – nuclear interaction
- 2 mW heat input expected
  with 6 x 10^7 pions/s
- 5 mW cooling power at 70mK

Target cell

- Target area: 130 cm long with < ±30 ppm
- 10 cm gap
  3 cells (27.5, 55, 27.5cm long)
- 20 cm gap
  2 cells (50, 50 cm long)





Proton target materials

Figure of Merit

$$PT_{FoM} = f^2 \times P_T^{\ 2} \times \rho \times F_f$$

f : dilution factor

ρ : density

F_f : packing factor

	H-butanol	NH_3	^{7}LiH
P_T	0.90	0.90	0.56 (H) * 0.38 (^{7}Li)
ρ	0.985	0.853	0.820
f	0.135	0.176	0.125 (H) 0.125 (^{7}Li)
F_f	0.62	0.50	0.55
PT_{FoM}	1	1.2	0.7

-Normalized by H-butanol

-Magnetic field 2.5T

- Relaxation time NH3 4000h at 60 mK and 0.6T

- If ^{7}LiH reach 90%, PT_{FoM} is 2.1.

* J. Ball, NIM. A 526 (2004) 7.

Deuteron target materials

Figure of Merit

$$PT_{FoM} = f^2 \times P_T^{\ 2} \times \rho \times F_f$$

f : dilution factor

ρ : density

F_f : packing factor

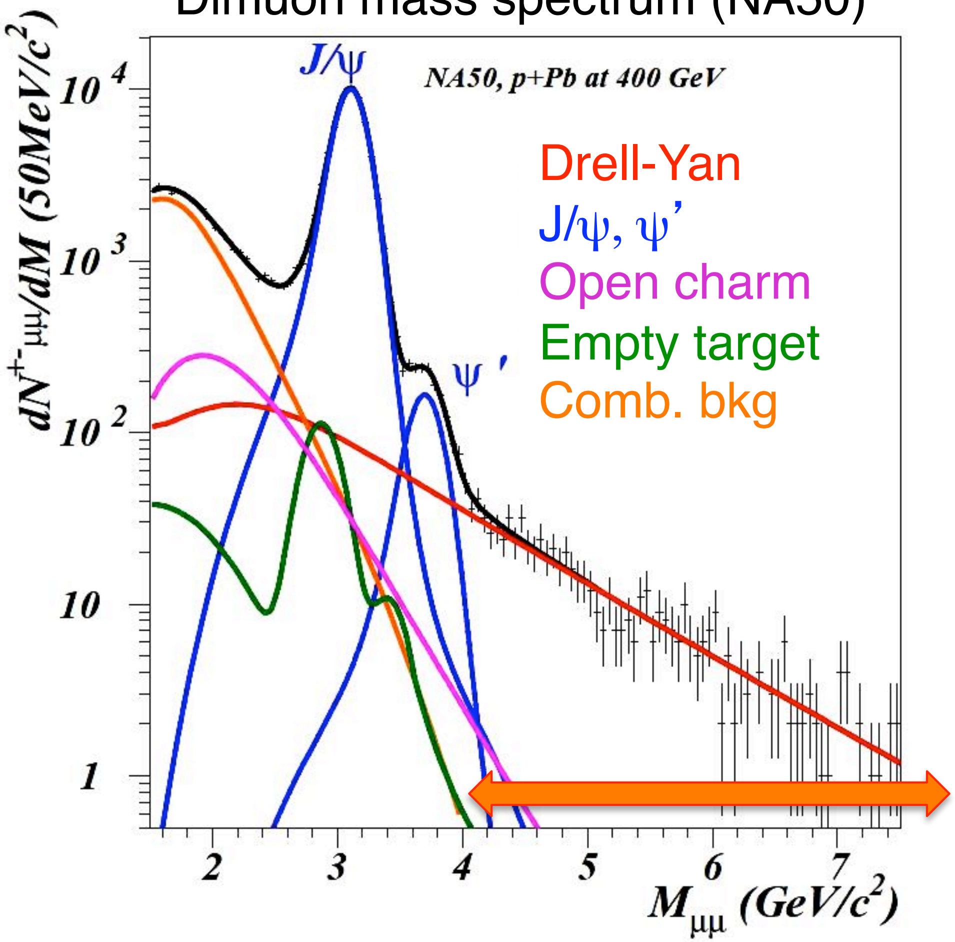
	ND_3	D- butanol	^{6}LiD
P_T	0.30 – 0.40	0.80 **	0.55 (H) 0.54 (^{6}Li)
ρ	1.00	1.12	0.820
f	0.300	0.238	0.250 (H) 0.250 (^{7}Li)
F_f	0.58	0.62	0.52
PT_{FoM}	1 – 1.8	5.4	6.9

-Normalized by ND_3 .
-Magnetic field 2.5T
- Relaxation time
^{6}LiD 2000h at 0.42T and 60 mK.

** S.T. Goertz et al,
NIM. A 526 (2004) 43.

Signal and background

Dimuon mass spectrum (NA50)



<u>2 backgrounds sources</u>

- Physics background
  $D, \bar{D}$ and J/ψ decays to $\mu^{+}\mu^{-}X$

- Combinatorial background
  π and K decaying to $\mu\nu$

Better region to study Drell-Yan is 4 < M GeV/c².

Some indications for statistics

$$\delta A = \frac{1}{P_T f} \frac{1}{\sqrt{N_{sig}}} \sqrt{1 + \frac{N_{sig}}{N_{backg}}}$$

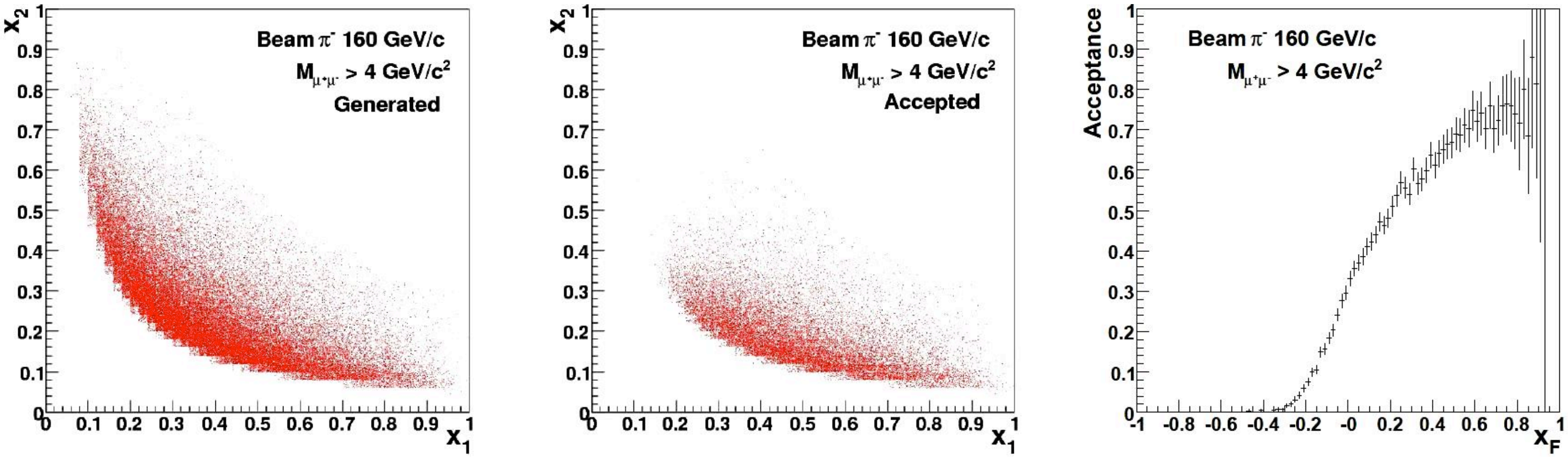
$$\tau = x_a x_b = M^2/s$$

- High luminosity (DY Cross Section is a fractions of nanobarns) and large angular acceptance, better pion or antiproton beams (valence anti-quark)
- Sufficiently high energy to access 'safe' of background free M_{ll} range (4 GeV/c < M_{ll} < 9 GeV/c)
- Good acceptance in the valence quark range $x_B > 0.1$ and kinematic range: $\tau = x_A x_B = M^2/s > 0.1$
- Good figure of merit (PT_{FoM}), which can be represented as a product of the luminosity and beam (target) polarization (dilution factor) ($PT_{FoM} \sim L \times P_{beam}$ *(f))*

Cross section and acceptance

From Pythia:

σ^{DY} (nb)	$2.0 < M_{\mu\mu} < 2.5$ (GeV/c^2)	$4. < M_{\mu\mu} < 9.$ (GeV/c^2)
s=100 GeV^2, p_π=73 GeV/c	0.9	0.03
s=200 GeV^2, p_π=106 GeV/c	1.2	0.10
s=300 GeV^2, p_π=160 GeV/c	1.4	0.17
s=400 GeV^2, p_π=213 GeV/c	1.6	0.24



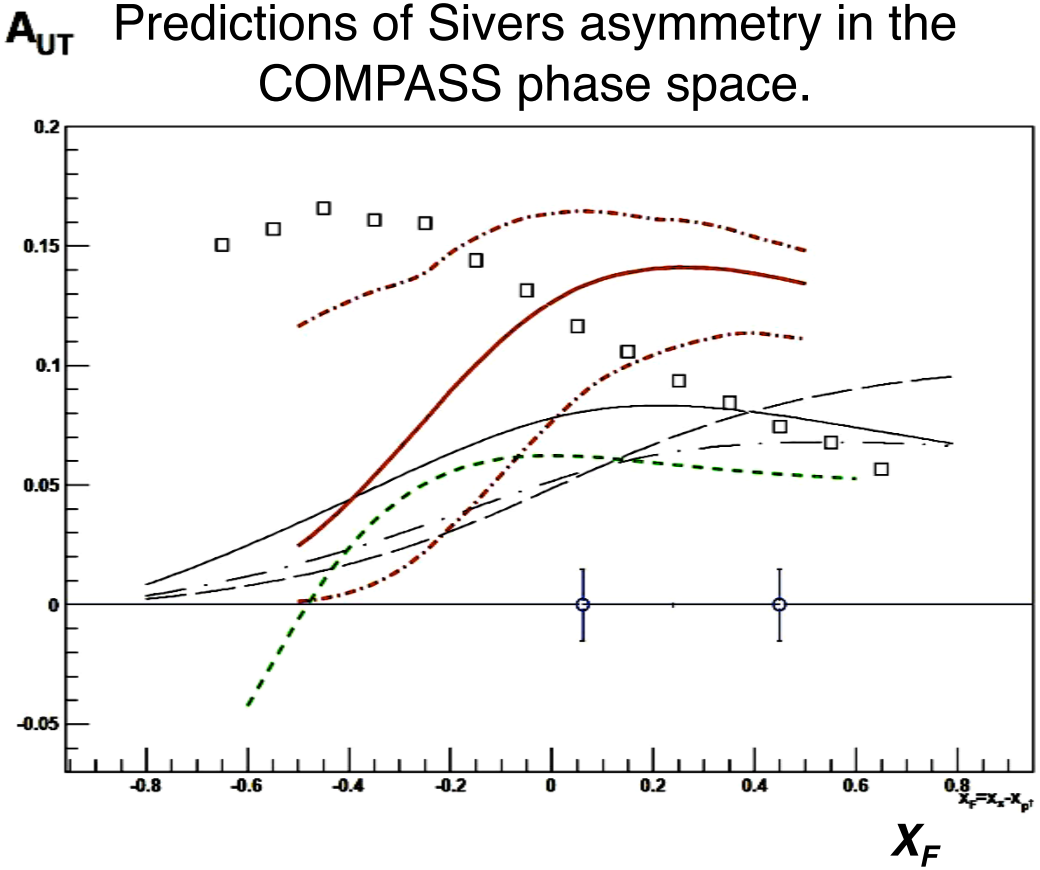
COMPASS acceptance is in the valence quarks regions (x > 0.1). This is also the best region to measure the spin asymmeties, as expected from theory predictions.

Expected statistical error for Sivers asymmetry

•With a beam intensity of 6 x 10^7 particles/s, a luminosity of 1.7 x 10^{33} /cm^{2}s can be obtained.
•Assuming 2 years of data-taking, more than 200k DY events in the region $4 < M < 9$ GeV/c^2.

•Solid and dashed: Etremov et. Al, PLB612(2005)233.
•Dot-dashed; Collins et al, PRD73(2006)014021.
•Solid, dot-dased; Ansemino et al, PRD79(2009)054010.
•Bixes; Blanconi et al, PRD73(2006)114002.
•Short-dashed; Bacchetta et al; PRD78(2008)074010.

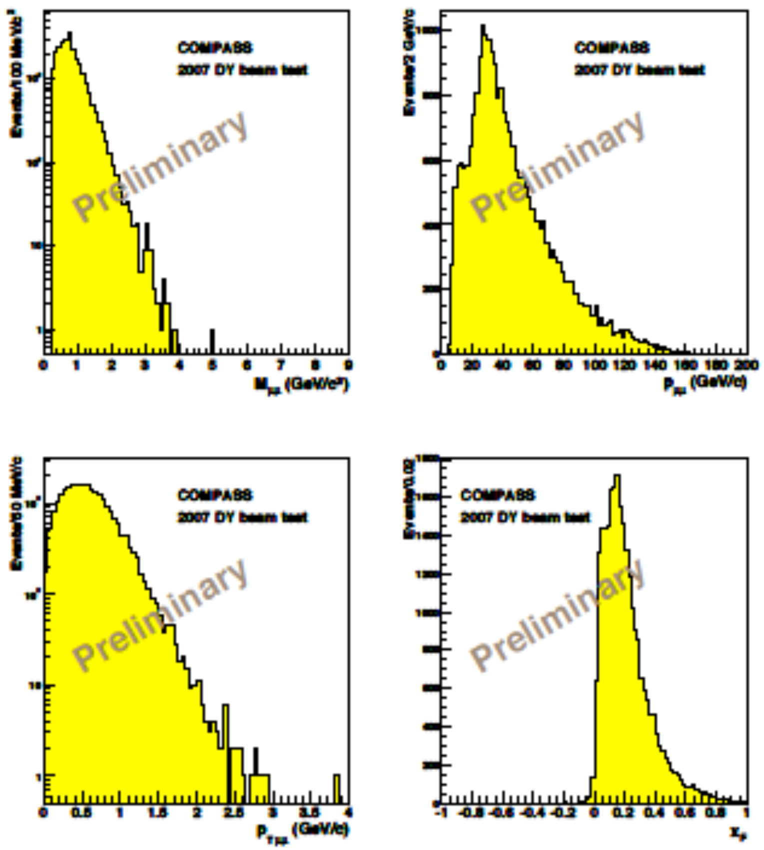
Predictions of Sivers asymmetry in the COMPASS phase space.

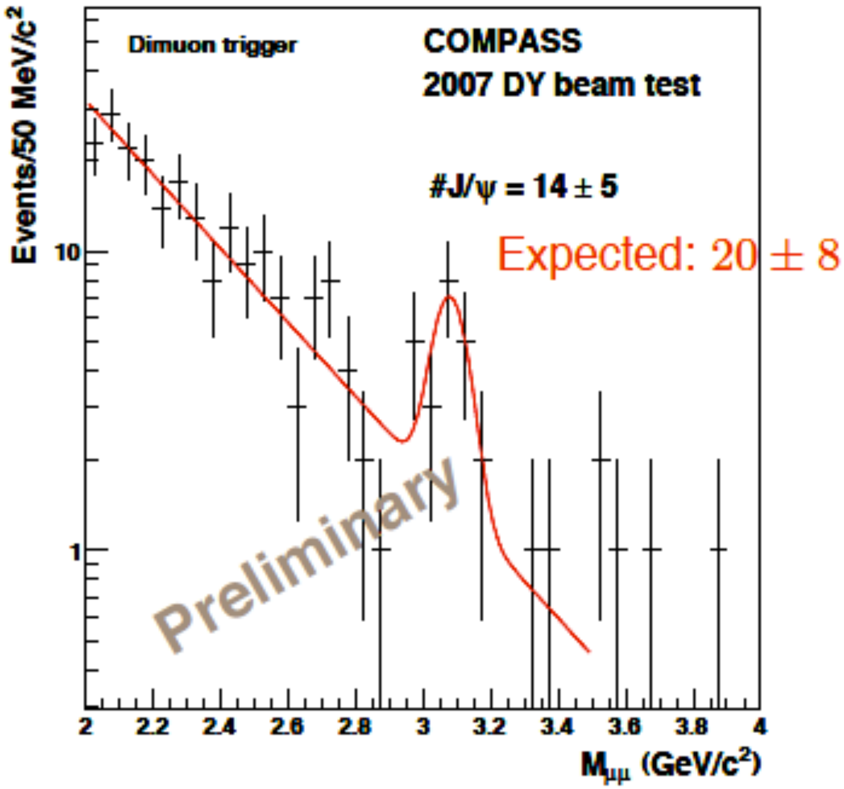


Beam test in 2007

Feasibility test at COMPASS

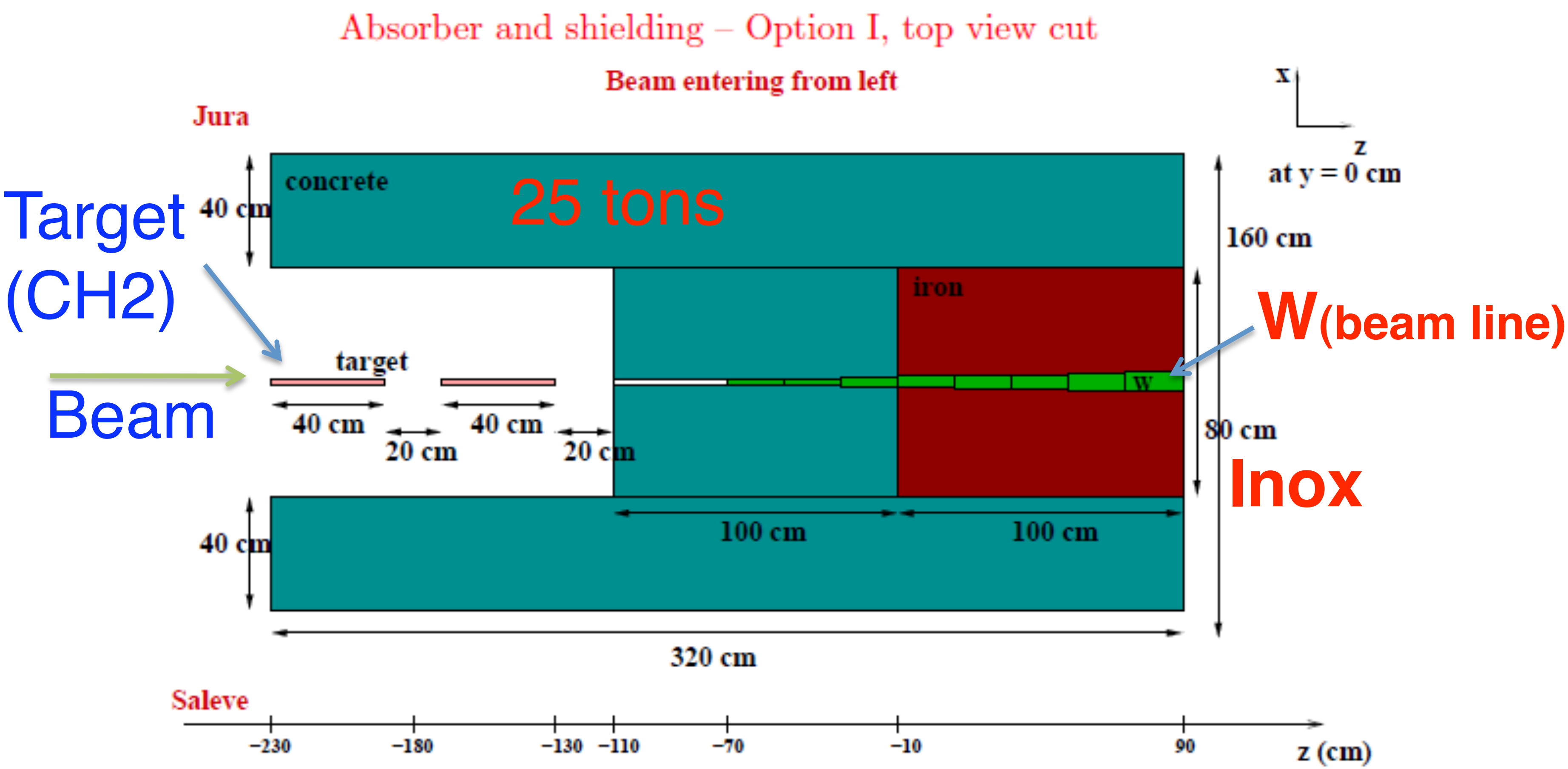
In 2007, with a π^- beam of 160 GeV/c on a NH_3 target, and without hadrons absorber: ≈ 90000 dimuon events (< 12 hours data-taking).





Beam test in 2009

Setup of target region for 2009 beam test



summary

• COMPASS will be able to perform several combinations of beams (π^-, π^+, *p(?))* and targets (*p* , *D*) for Drell-Yan measurement. ↑ ↑

•We will perform the first measurement with π- beam and transversal polarized *p* target.

•The expected accuracy after 2 years data taking is enough to provide unique information of hadron structure and of transverse momentum PDFs.