Future Drell-Yan measurements @ COMPASS

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Transversity 2008
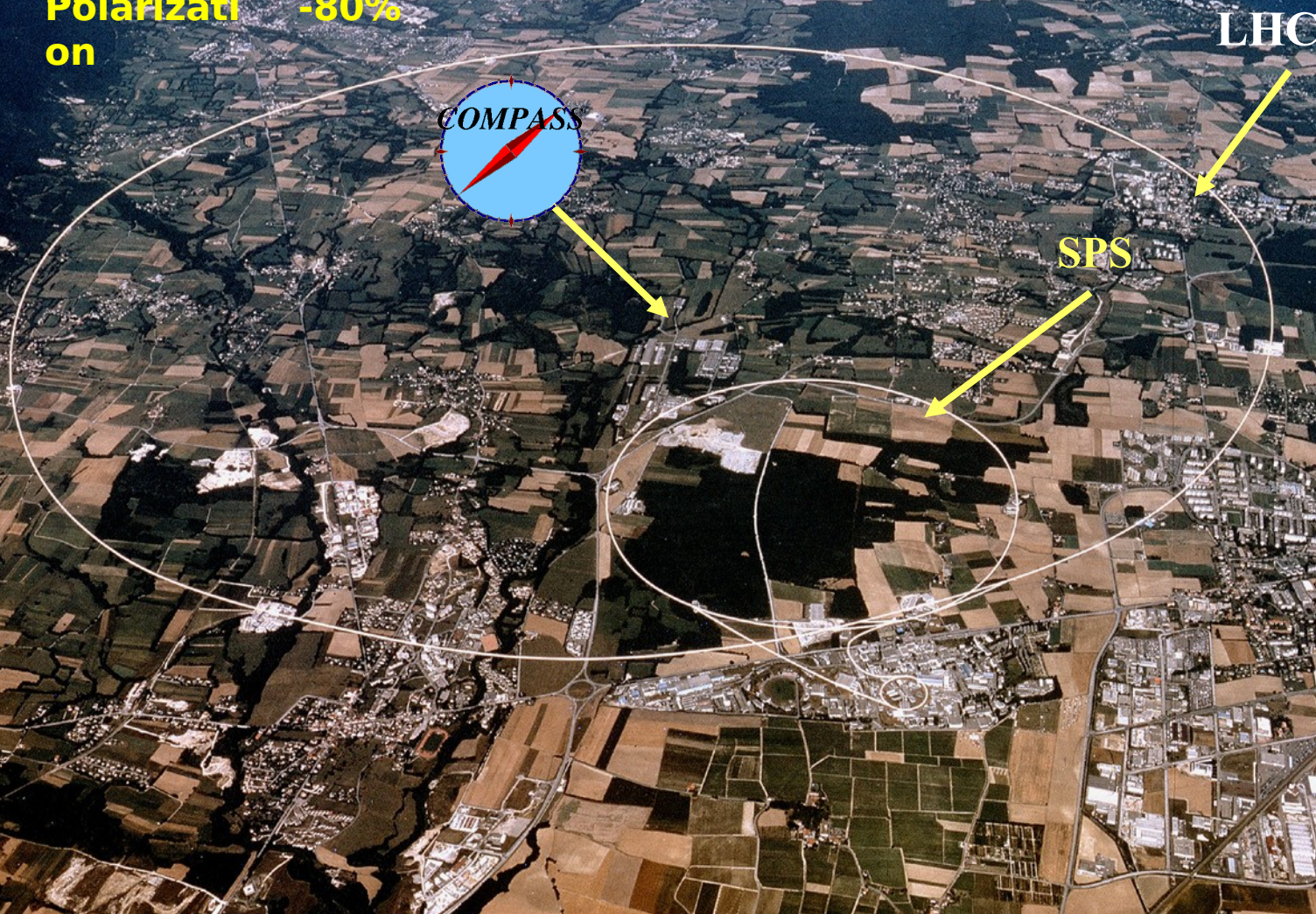
COMPASS is a fixed target experiment at CERN
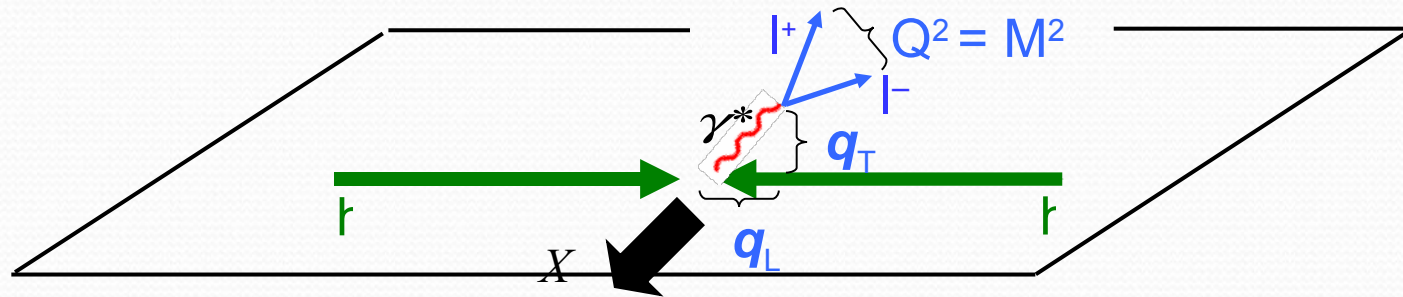
		Muons	**Hadrons (p, π/K)**
Beam:	**Intensity**	**2 10⁸ μ⁺/spill (4.8s, 16.2s)**	**Max 1· 10⁸ h/spill**
	Momentum	**160 GeV/c**	**(50 – 270) GeV/c**
	Polarization	**-80%**	

COMPASS

LHC

SPS

N

Drell-Yan di-lepton production

l^+ $Q^2 = M^2$

l^-

γ^*

q_T

q_L

X

Electromagnetic process

factorization holds, two scales, *M²*, and q_T

$$x_f = x_1 - x_2 = \frac{2p_L}{\sqrt{S}}$$

$$\tau = \frac{M^2}{S} = x_1 \cdot x_2$$

$$\mathrm{d}\sigma^{D-Y} = \sum_q f_q(x_1, \boldsymbol{k}_\perp; Q^2) \otimes f_{\bar{q}}(x_2, \boldsymbol{k}_\perp; Q^2)\, \mathrm{d}\hat{\sigma}^{q\bar{q}\to l^+l^-}$$

DY reaction allows to measure the *parton distribution functions* without the convolution with the fragmentation functions

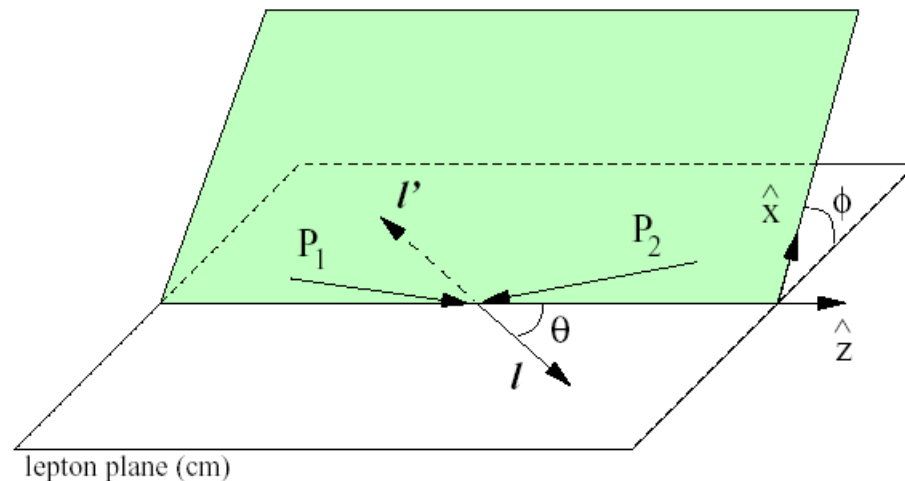# Why Drell-Yan @ COMPASS?!

- Clean method to study PDF $\rightarrow$ no convolution with FF

$$\pi^- p^\uparrow \rightarrow \mu^+\mu^-X \,; \ \pi^- p \rightarrow \mu^+\mu^-X \rightarrow \text{flavor separation } (\bar{u}u)$$

$$\pi^+ p^\uparrow \rightarrow \mu^+\mu^-X \,; \ \pi^+ p \rightarrow \mu^+\mu^-X \rightarrow \text{flavor separation } (\bar{d}d)$$

- $x_1, x_2 > 0.1$
- Intense (10^8 h/spill) hadron beam
- Polarized target
- Large acceptance spectrometer
- Possibility to trigger on both muons and electrons
- COMPASS is a running experiment

The unpolarized case: π p→μ⁺μ⁻X

Collins-Soper frame

lepton plane (cm)

$$\frac{1}{\sigma}\frac{d\sigma}{d\Omega} = \frac{3}{4\pi}\frac{1}{\lambda+3}\left(1+\lambda\cos^2\theta+\mu\sin^2\theta\cos\phi+\frac{\nu}{2}\sin^2\theta\cos 2\phi\right)$$

PRD39,92(1989)

Collinear factorization:

Parton Model $O(\alpha^0_s)$ $\lambda= 1, \mu = \nu= 0$

LO pQCD $O(\alpha^1_s)$ $1-\lambda -2\nu= 0$ Lam-Tung relation

NLO $O(\alpha^2_s)$ $1-\lambda -2\nu \neq 0$ small and positive

ν ~ 30% possible explanations :
- higher twist effects
- factorization breaking
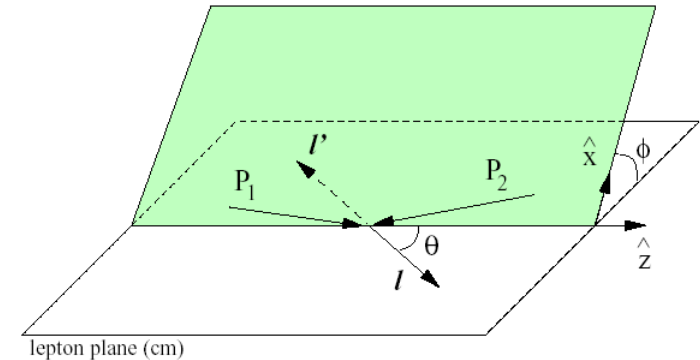- Boer's Model → transverse momentum dependent PDF (at LO) PRD 65, (2002)034008

COMPASS DY : π⁻p→μ⁺μ⁻X

Use of **unpolarized** Drell-Yan π⁻p→μ⁺μ⁻X

$$\hat{R} = \frac{\int d^2 q_T \left[|q_T|^2 / M_\pi M_p \right] \cdot \left[d\sigma^0 / d\Omega \right]}{\int d^2 q_T \sigma^0}$$

lepton plane (cm)

can be parametrized

$$\hat{R} = \frac{3}{16\pi} \left[\gamma \left(1 + \cos^2 \theta \right) + \hat{k} \cos 2\phi \sin^2 \theta \right]$$

All angles are defined in the Lepton CM frame.

$$\hat{k}\left(x_\pi, x_p \right) = 8 \frac{\left[\bar{h}_{1\bar{u}}^{\perp(1)}\left(x_\pi \right) \big|_{\pi^-} \cdot h_{1u}^{\perp(1)}\left(x_p \right) \big|_p \right]}{\left[\bar{f}_{1\bar{u}}^{(1)}\left(x_\pi \right) \big|_{\pi^-} \cdot f_{1u}^{(1)}\left(x_p \right) \big|_p \right]}$$

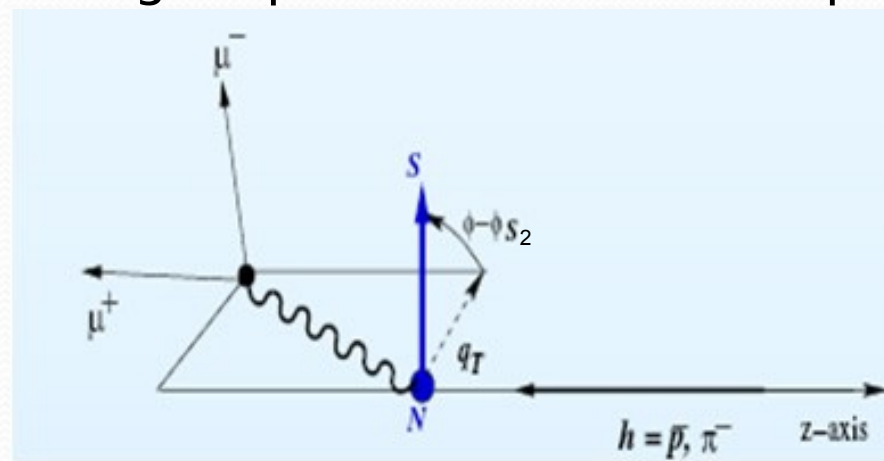## **First Moment of Boer-Mulders function**

COMPASS DY : $\pi^- p^\uparrow \rightarrow \mu^+ \mu^- X$ the

golden channel to measure the transversity distribution

Use of single **polarized** Drell-Yan $\pi^- p^\uparrow \rightarrow \mu^+ \mu^- X$ $SSA = \dfrac{d\sigma^\uparrow - d\sigma^\downarrow}{d\sigma^\uparrow + d\sigma^\downarrow}$

: azimuthal angle of the target spin vector wrt the lepton plane

: target spin vector

$$A^{\sin(\psi)} = \frac{\int d\Omega d\phi_{S2} \int d^2 q_T \left(|q_T|/M_\pi\right) \sin \psi \left[d\sigma(S_{pT}) - d\sigma(-S_{pT}) \right]}{\int d\Omega d\phi_{S2} \int d^2 q_T \left[d\sigma(S_{pT}) + d\sigma(-S_{pT}) \right]}$$

$\Psi = \varphi + \varphi_{s2}$
Transversity

$\Psi = \varphi - \varphi_{s2}$
Sivers

COMPASS DY :

Boer Mulders function

Unpolarized DY

$$\hat{k}(x_\pi, x_p) \propto \frac{\left[\bar{h}_{1\bar{u}}^{\perp(1)}(x_\pi)\big|_{\pi^-} \cdot h_{1u}^{\perp(1)}(x_p)\big|_p\right]}{\left[\bar{f}_{1\bar{u}}^{(1)}(x_\pi)\big|_{\pi^-} \cdot f_{1u}^{(1)}(x_p)\big|_p\right]}$$

Boer Mulders function

Polarized DY

Transversity: $A^{\sin(\phi+\phi_{S2})}(x_\pi, x_p) \propto -\dfrac{\left[\bar{h}_{1\bar{u}}^{\perp(1)}(x_\pi) \cdot h_{1u}(x_p)\right]}{\left[\bar{f}_{1\bar{u}}(x_\pi) \cdot f_{1u}(x_p)\right]}$

Transversity function

Sivers function

Sivers: $A^{\sin(\phi-\phi_{S2})}(x_\pi, x_p) \propto \dfrac{\left[\bar{f}_{1\bar{u}}^{(1)}(x_\pi) \cdot f_{1T}^{\perp(1)}(x_p)\right]}{\left[\bar{f}_{1\bar{u}}(x_\pi) \cdot f_{1u}(x_p)\right]}$

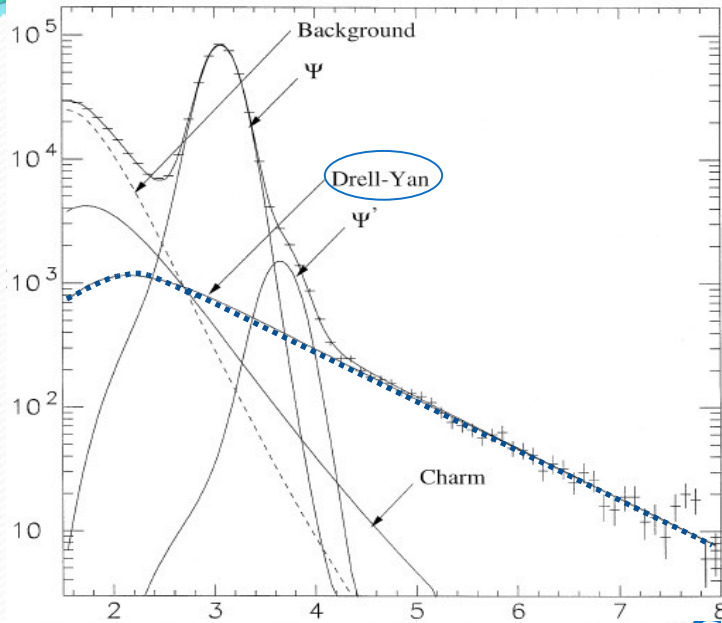$$f_{1T}^{\perp q}\big|_{SIDIS} = -f_{1T}^{\perp q}\big|_{DY}$$

Fundamental QCD prediction
Collins, PLB536, 43(2002)

COMPASS spectrometer layout

$10^8\ \pi$/spill

Polarized Target
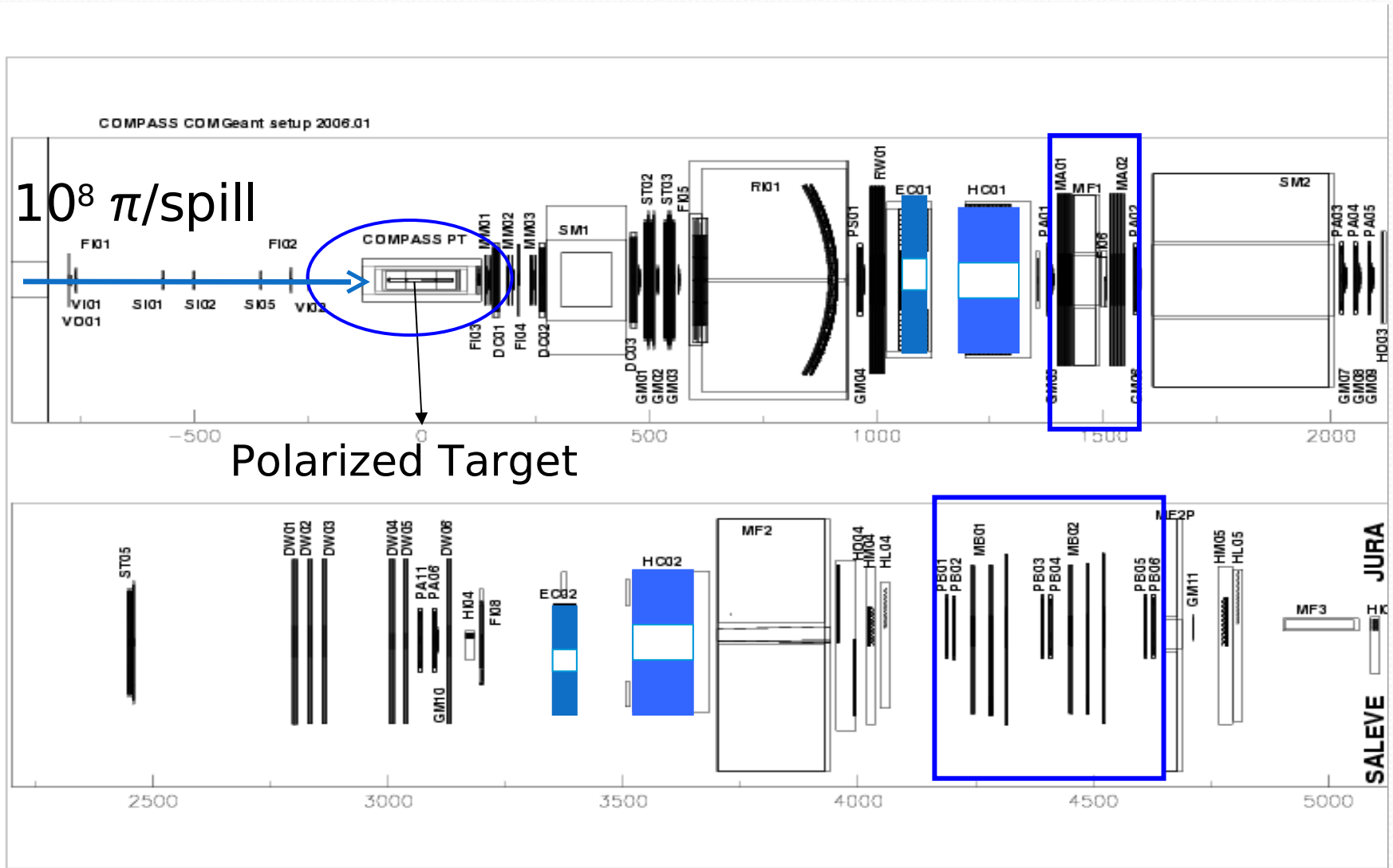
Kinematic range

$_{\pi\text{-beam}}$= 50-300 GeV
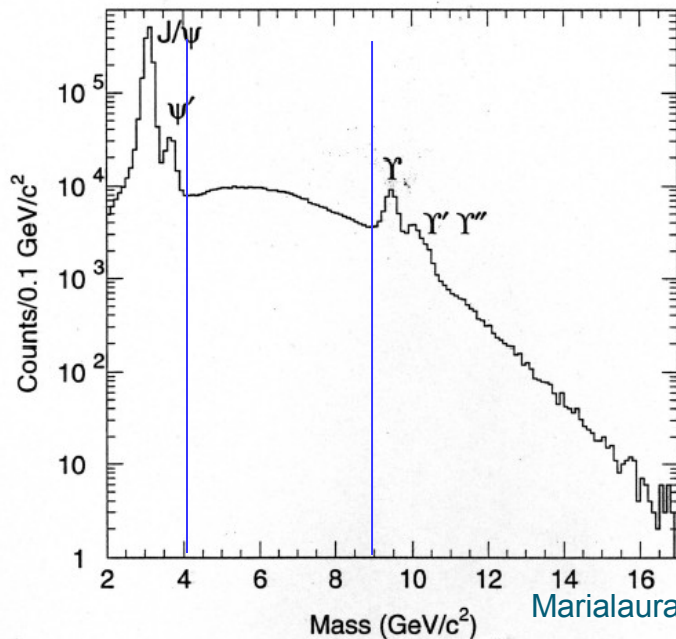
must be large enough to apply pQCD

roduction rate falls off rapidly with M^{-4}

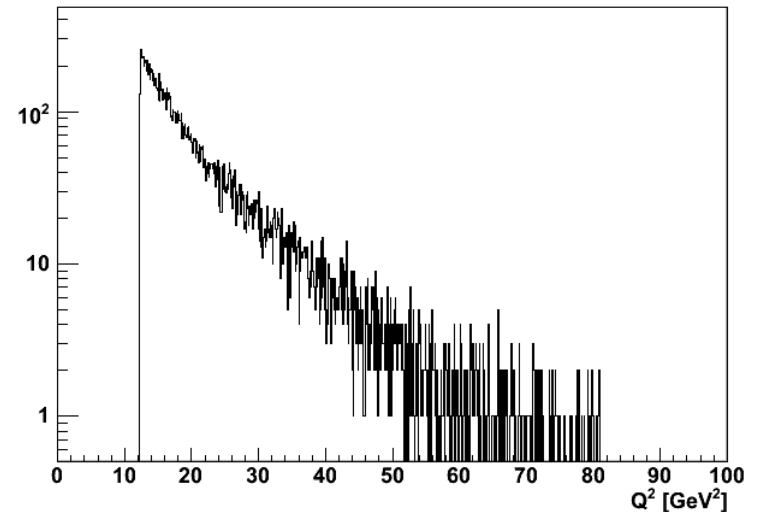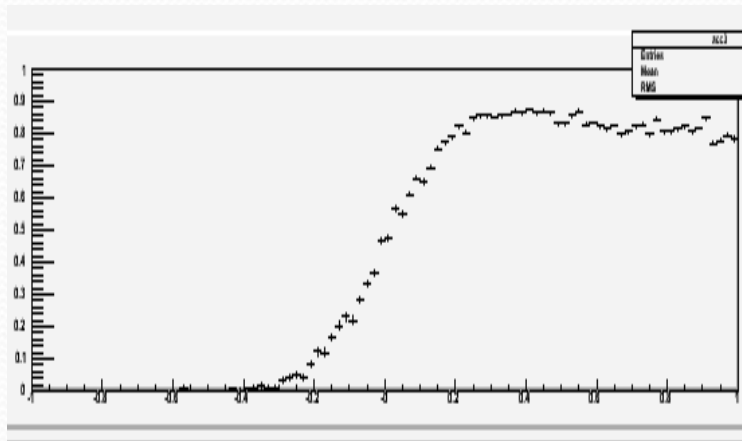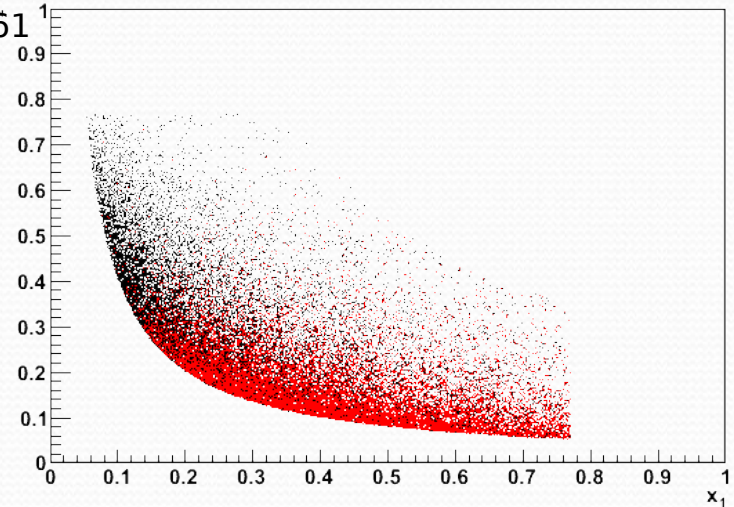alence quarks region (x1, x2) > 0.1 has t
e covered

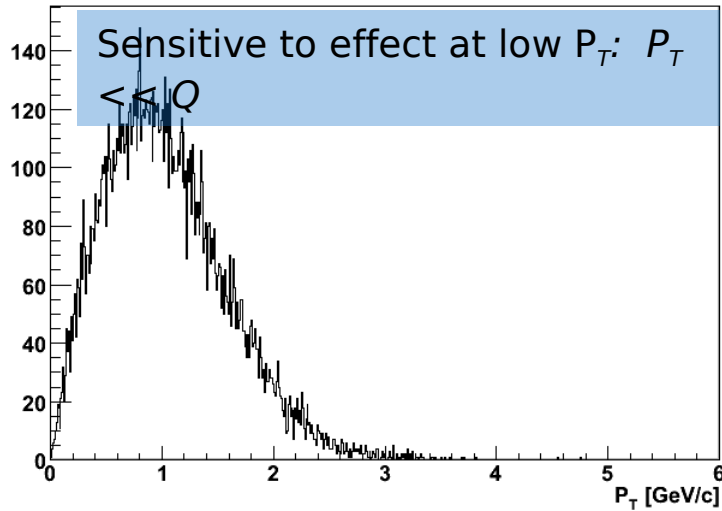**Safe region**

M interval out of the resonances region
to be selected (4 GeV/c² < M < 9.0 GeV/c²)

Generator input:

E_{beam} = 160 GeV/c

p: GRV 98 low, q^2_{min} = 0.8 Eur.Phys.J. C5 (1998) 461

π: GRV-P LO, q^2_{min} = 0.25

Sensitive to effect at low P_T: $P_T << |Q|$

OMPASS vs other experiments

Cern WA39
Ω 40 GeV/c
ψ

Cern R 209
CHFMNP
$\sqrt{s} = 62$

Cern NA3
NA 3
200 GeV/c

Fnal 288
CFS ϒ 400 GeV/c
CFS 200 GeV/c

Fnal E615

Fnal E866
for sea $\bar{q}$
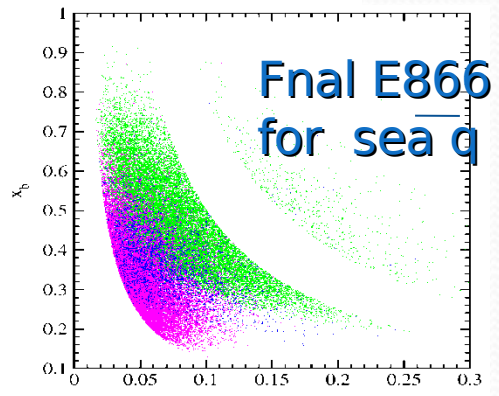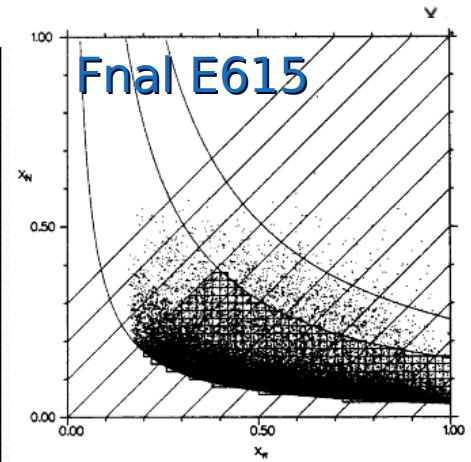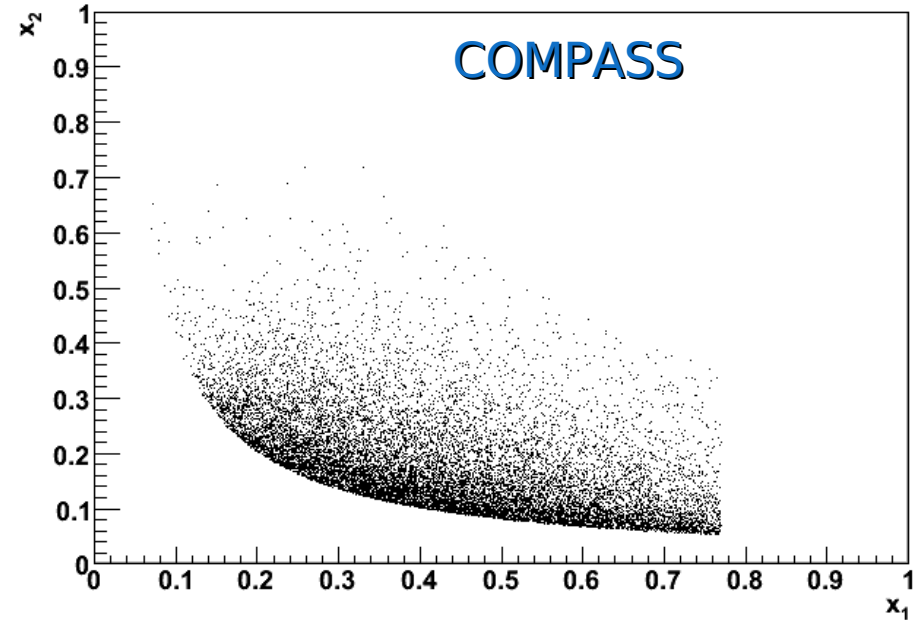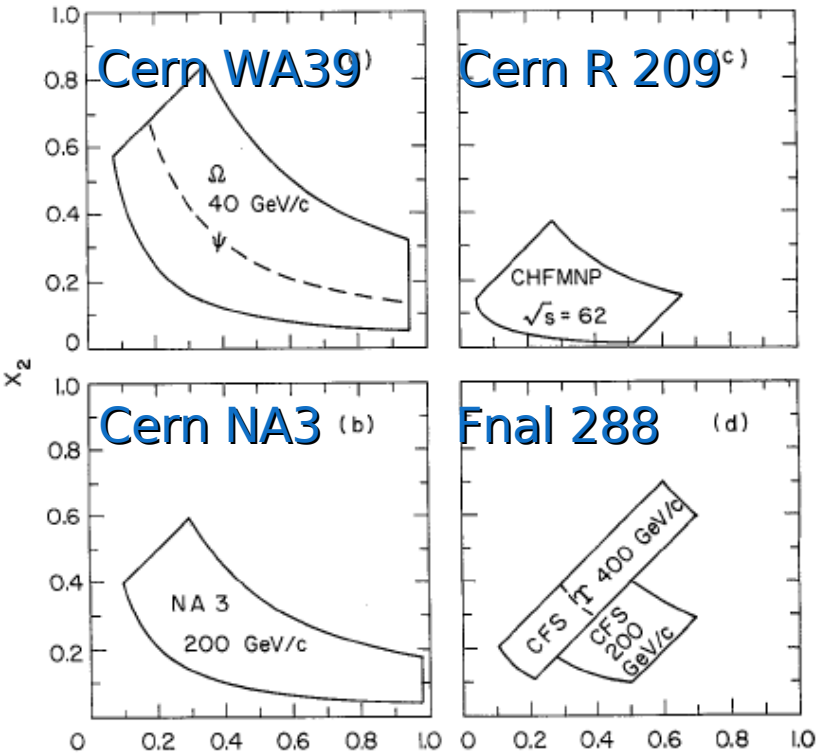
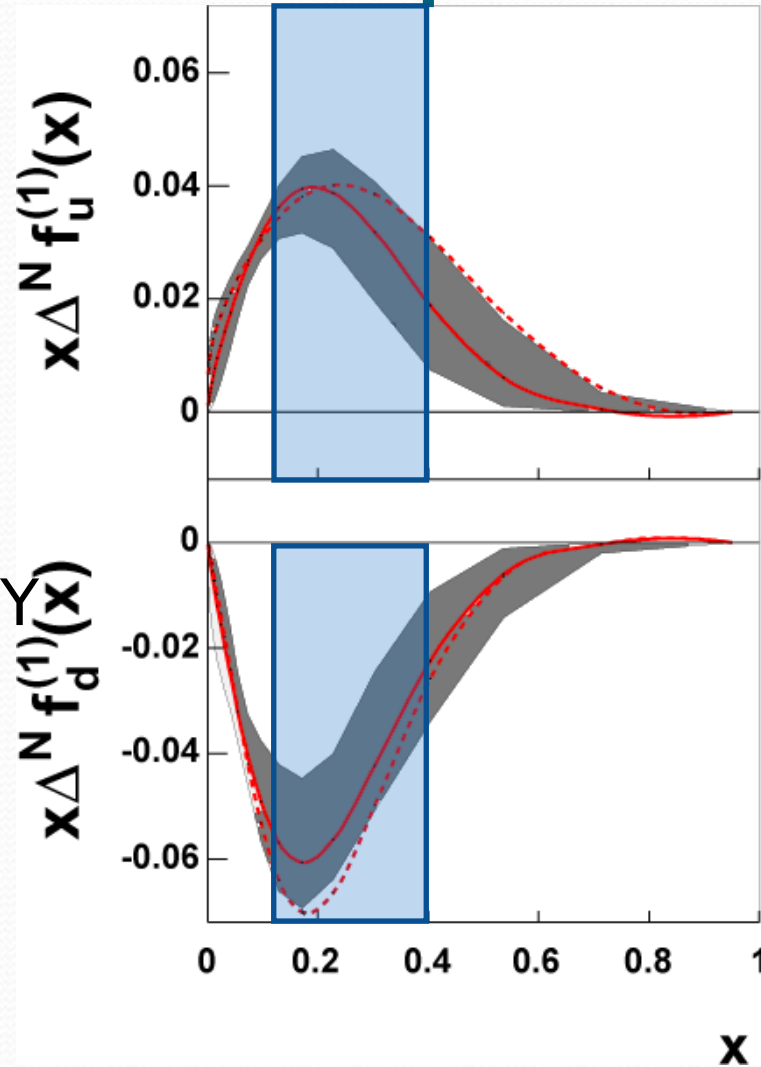COMPASS

Good acceptance in the valence quark region
Overlap with past experiment
+ polarized target

vs COMPASS acceptance.

Sivers distribution
function for u, d flavor
for SIDIS
sign to be reversed for DY

COMPASS 2007 test for DY measurement conditions

- Conditions:
  - π^- beam of 160 GeV/c
  - Beam intensity is $4 \cdot 10^6$ h/s^{-1}
  - Compass PT target (120 cm NH$_3$)
  - Luminosity 10^{31} cm^{-2}s^{-1}
  - Test duration is about 20 hours
- Results:
  - π^- beam is **OK**
  - Radiation condition in the area is **OK**
  - Spectrometer behavior is **OK**

Time scale

- This project will be a part of updated COMPASS proposal

- COMPASS spectrometer upgrade preparation: 2009-2010
  - Muon trigger in LAS
  - Radiation Hard central part of ECaI1

- First data with pion beam after 2010