PANDA Electromagnetic Working Group Meeting
Ferrara, 15 – 16 October 2007

DRELL YAN AT PANDA

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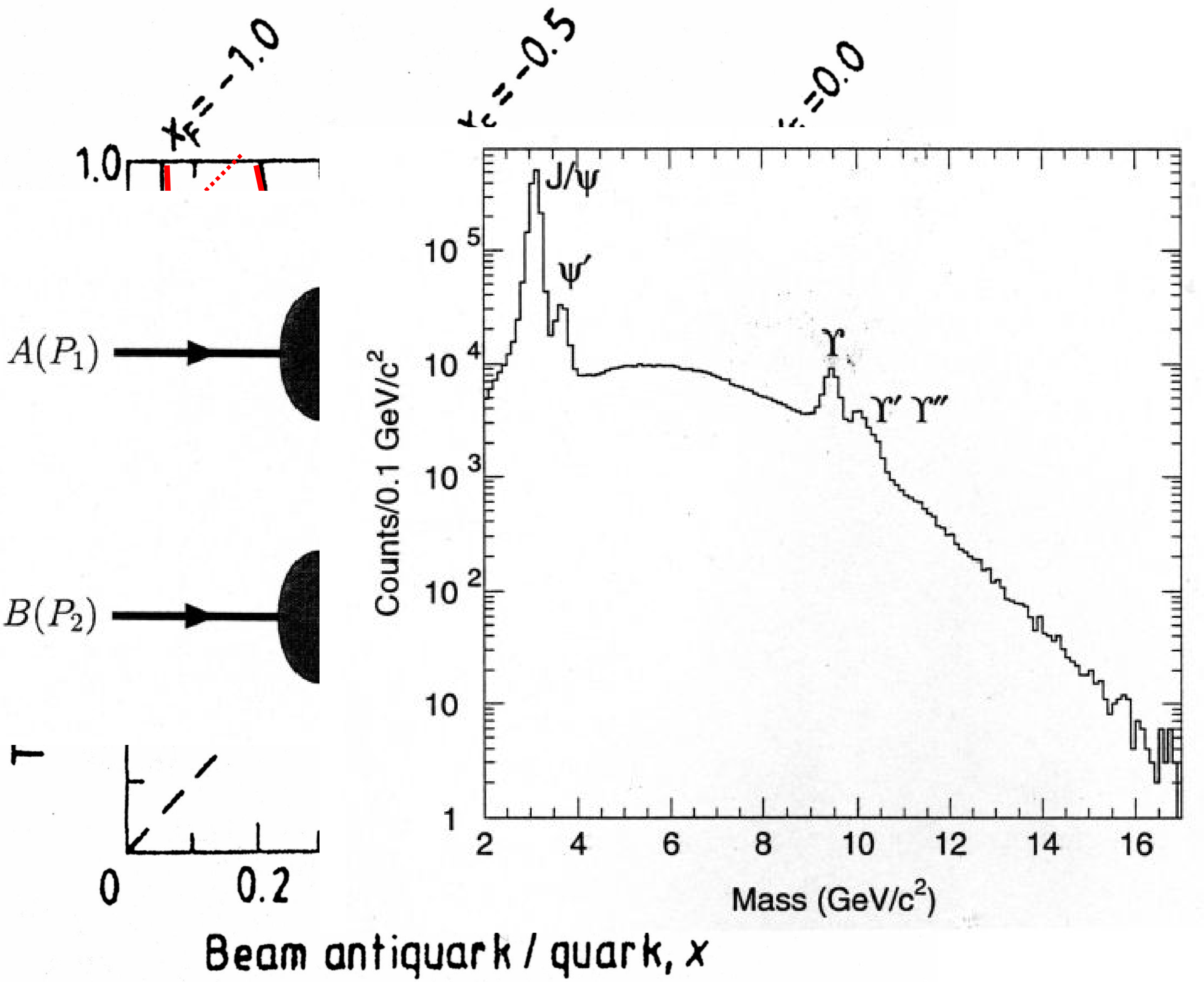
Introduction

A complete description of nucleonic structure requires:

- quark and gluon distribution functions
- quark fragmentation functions

@ leading twist and @ NLO (k_T dependence)

Phase space for Drell-Yan processes



yperbolae

iematics

$$x_2 = \frac{M^2}{2P_2 \cdot q}$$

$$x_F = x_1 - x_2$$

$$x_1 x_2 = \frac{M^2}{s}$$

Drell-Yan Asymmetries — $\bar{p}p \rightarrow \mu^+\mu^- X$

Di-Lepton Rest Frame

$$\frac{1}{\sigma}\frac{d\sigma}{d\Omega} = \frac{3}{4\pi}\frac{1}{\lambda+3}\left(1+\lambda\cos^2\theta+\mu\sin^2\theta\cos\varphi+\frac{\nu}{2}\sin^2\theta\cos2\varphi\right)$$

NLO pQCD: λ ~ 1, μ ~ 0, υ ~ 0 (including resummation[2])

Lam-Tung sum rule: 1- λ = 2ν

Experimental data [1]: υ ~ 30 % - Can be interpreted by ISI

[1] J.S.Conway et al., Phys. Rev. D39 (1989) 92. [2] D. Boer et al., Phys. Rev. D74 (2006) 014004.

υ involves transverse spin effects at leading twist [2]

If unpolarised DY σ is kept differential on k_T ,

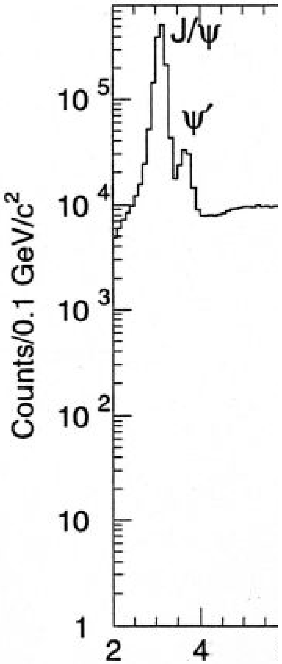
cos2φ contribution to angular distribution provide:

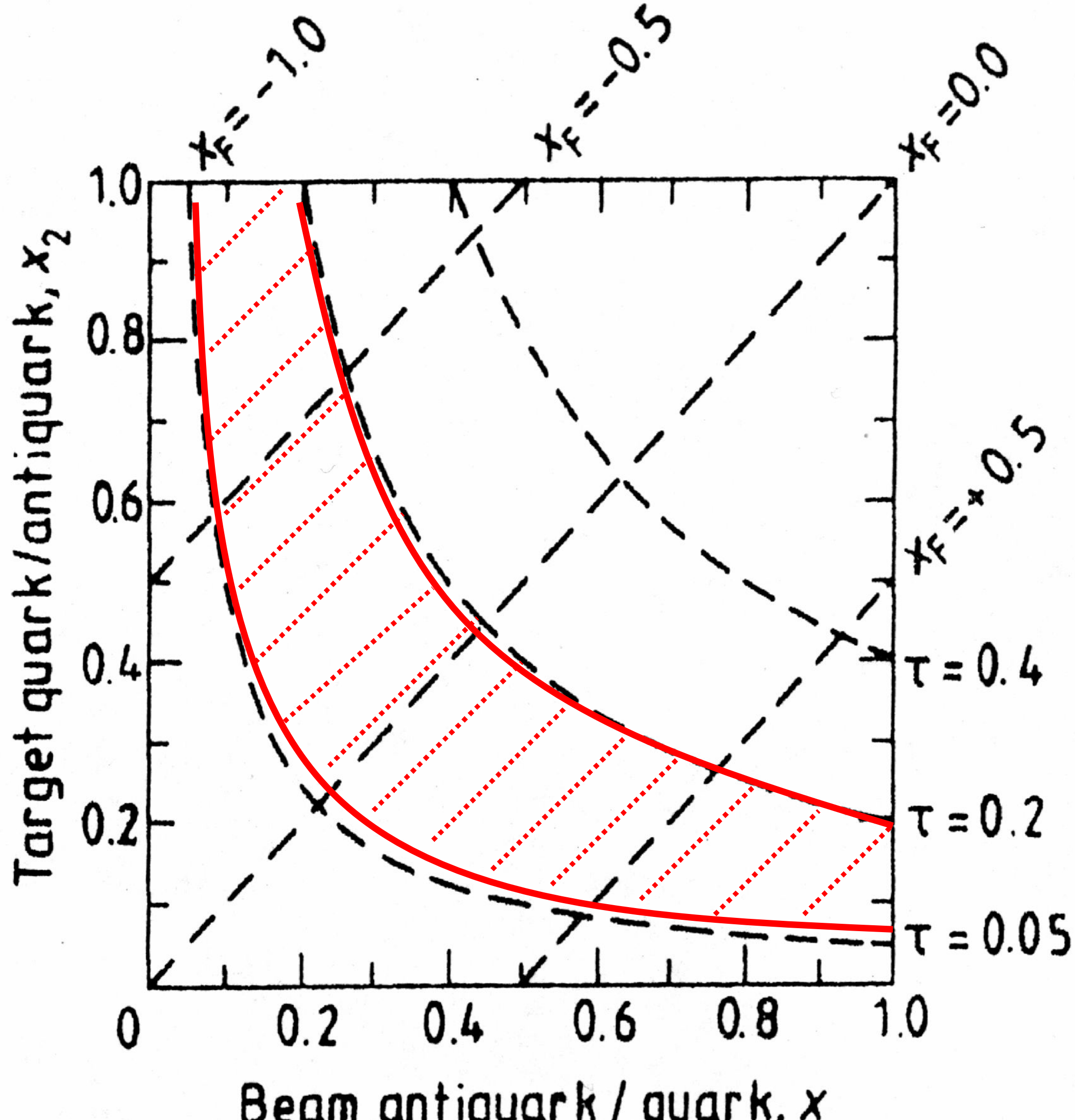
$$h_1^{¿}(x_2, \kappa_{¿}^2) \times \bar{h}_1^{¿}(x_1, \kappa_{¿}^{2}) ¿¿$$

[2] D. Boer et al., Phys. Rev. D60 (1999) 014012.

Unpolarised Drell-Yan Asymmetries — $\bar{p}\ p \to \mu^+ \mu^- X$

40 K e… GeV/c^2

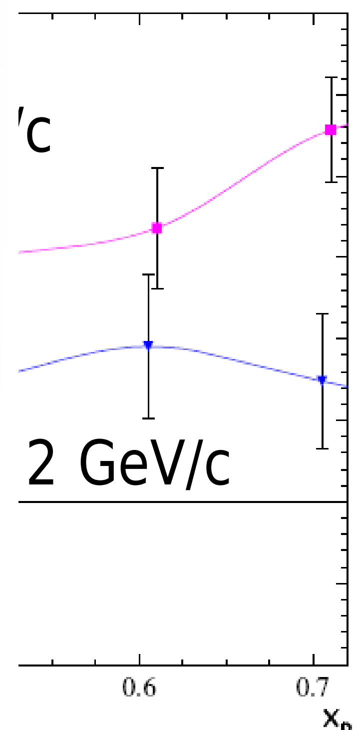




…etry

…tion

…'c



2 GeV/c

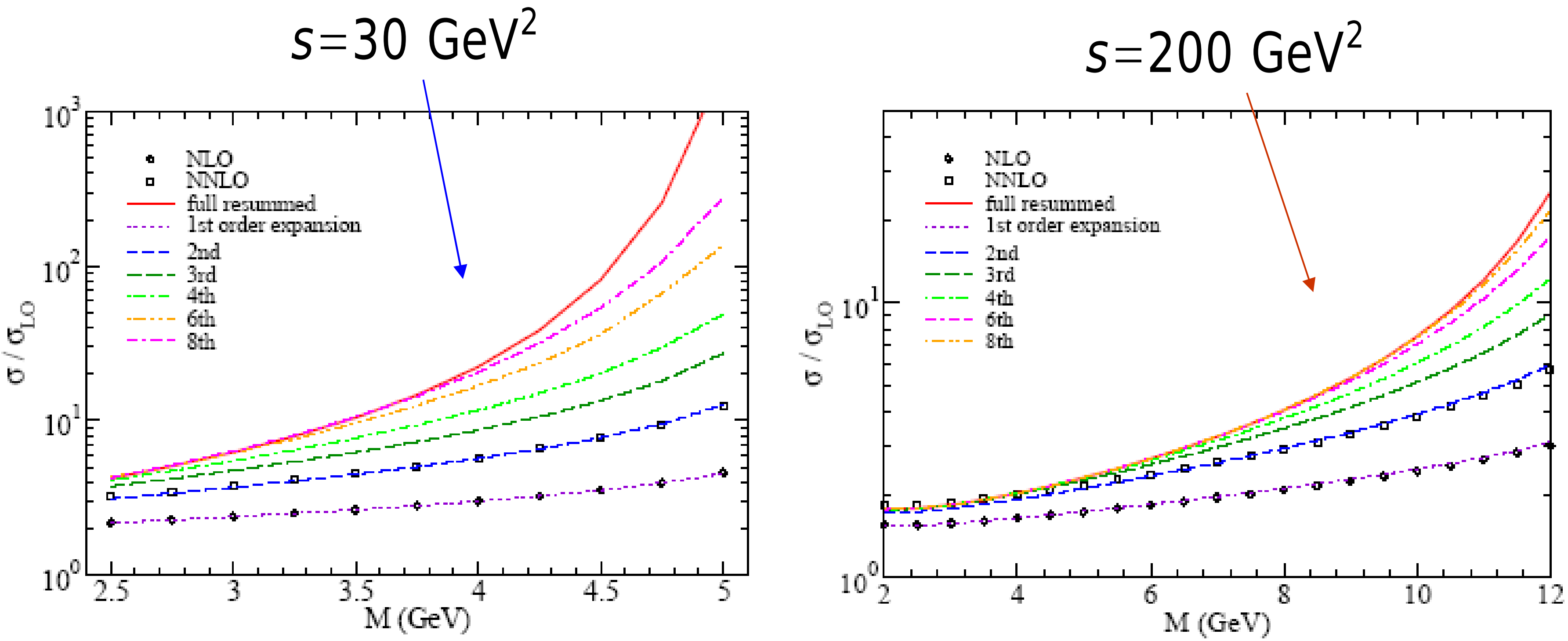
0.2 < …

error bars allo…

- small asymm…
- their depend…

[1]A. Bianconi and M. …

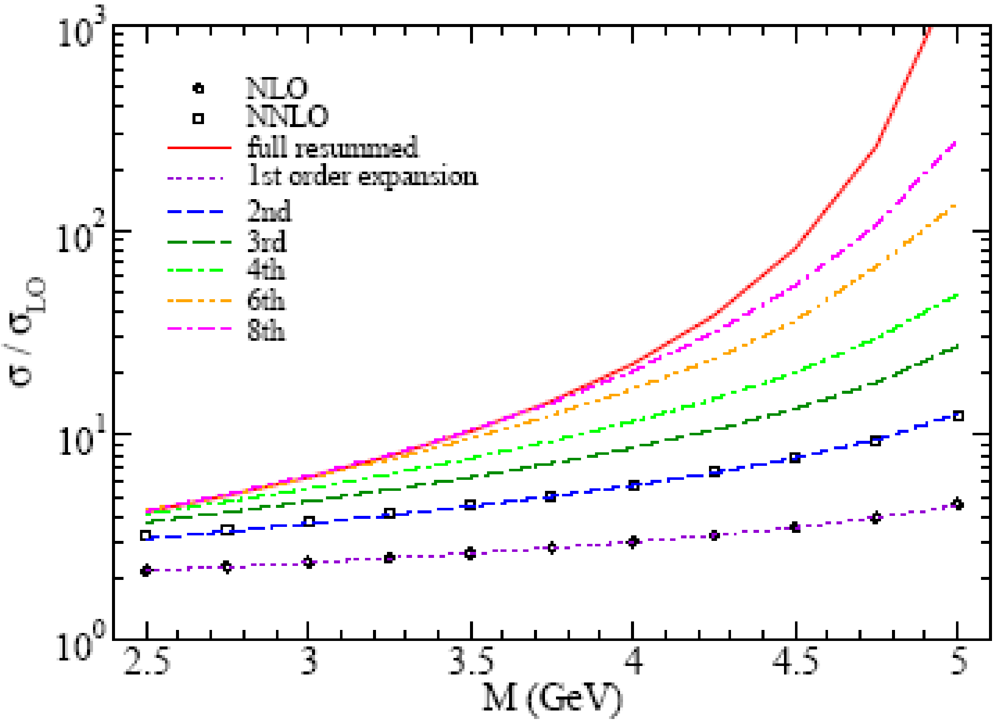
Drell-Yan Asymmetries — $\bar{p}\,p \to \mu^+ \mu^- X$



At higher energy (s ~ 200 GeV^2)
perturbative corrections[1] are sensibly smaller
in the safe region

[1]H. Shimizu et al., Phys. Rev. D71 (2005) 114007

Unpolarised Drell-Yan — $\bar{p}\,p \rightarrow \mu^{+}\mu^{-}X$



$s = 30\ \mathrm{GeV}^2$

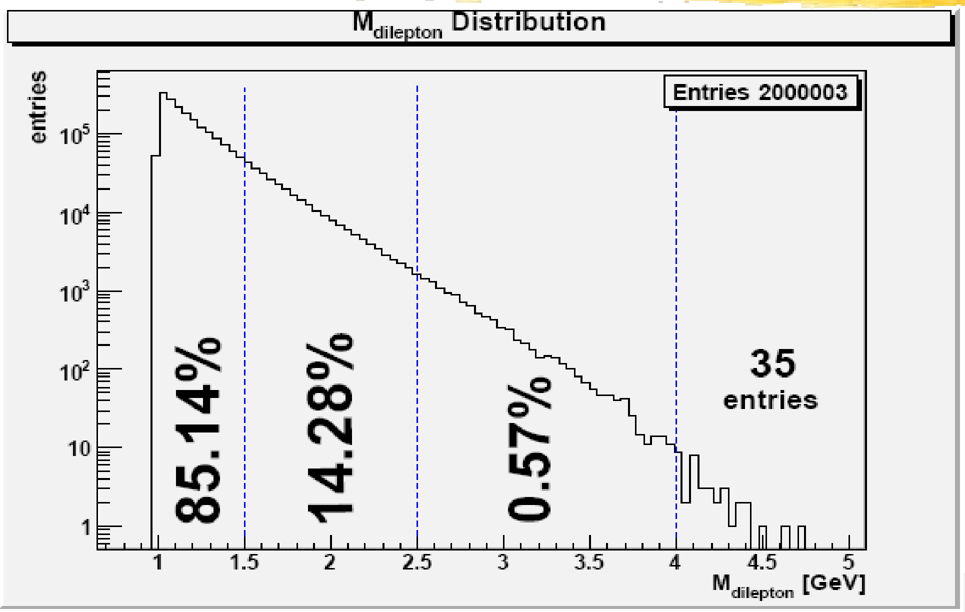
Perturbative corrections[1] are expected to be large in the PANDA energy range

Unpolarised DY cross-section allow the investigation of:

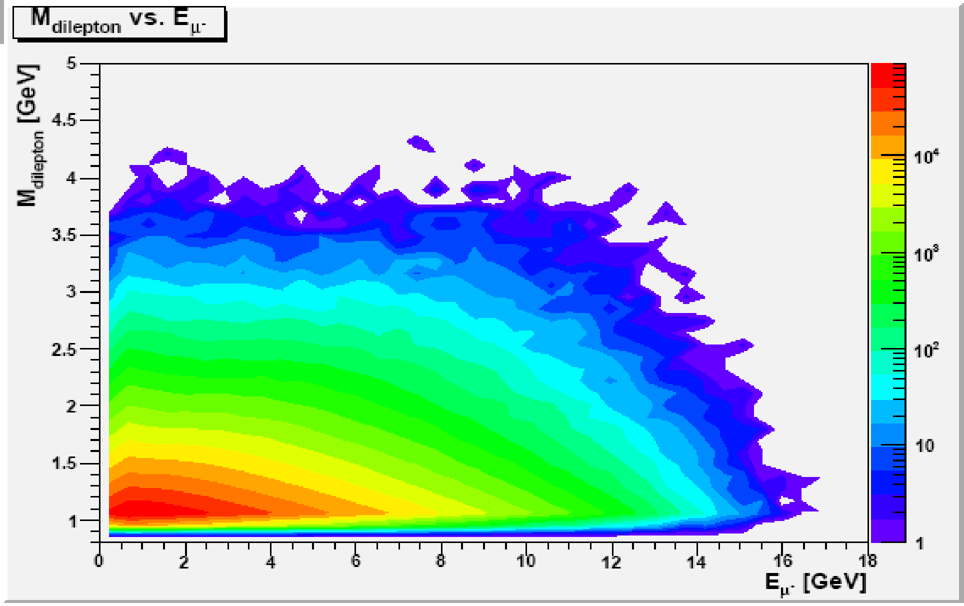
- limits of the factorisation and perturbative approach
- relation of perturbative and not perturbative dynamics in hadron scattering

[1]H. Shimizu et al., Phys. Rev. D71 (2005) 114007

Benchmark channel: DY @ 14 GeV/c — $\bar{p}p \rightarrow \mu^+\mu^- X$



ABianconi Drell - Yan Generator

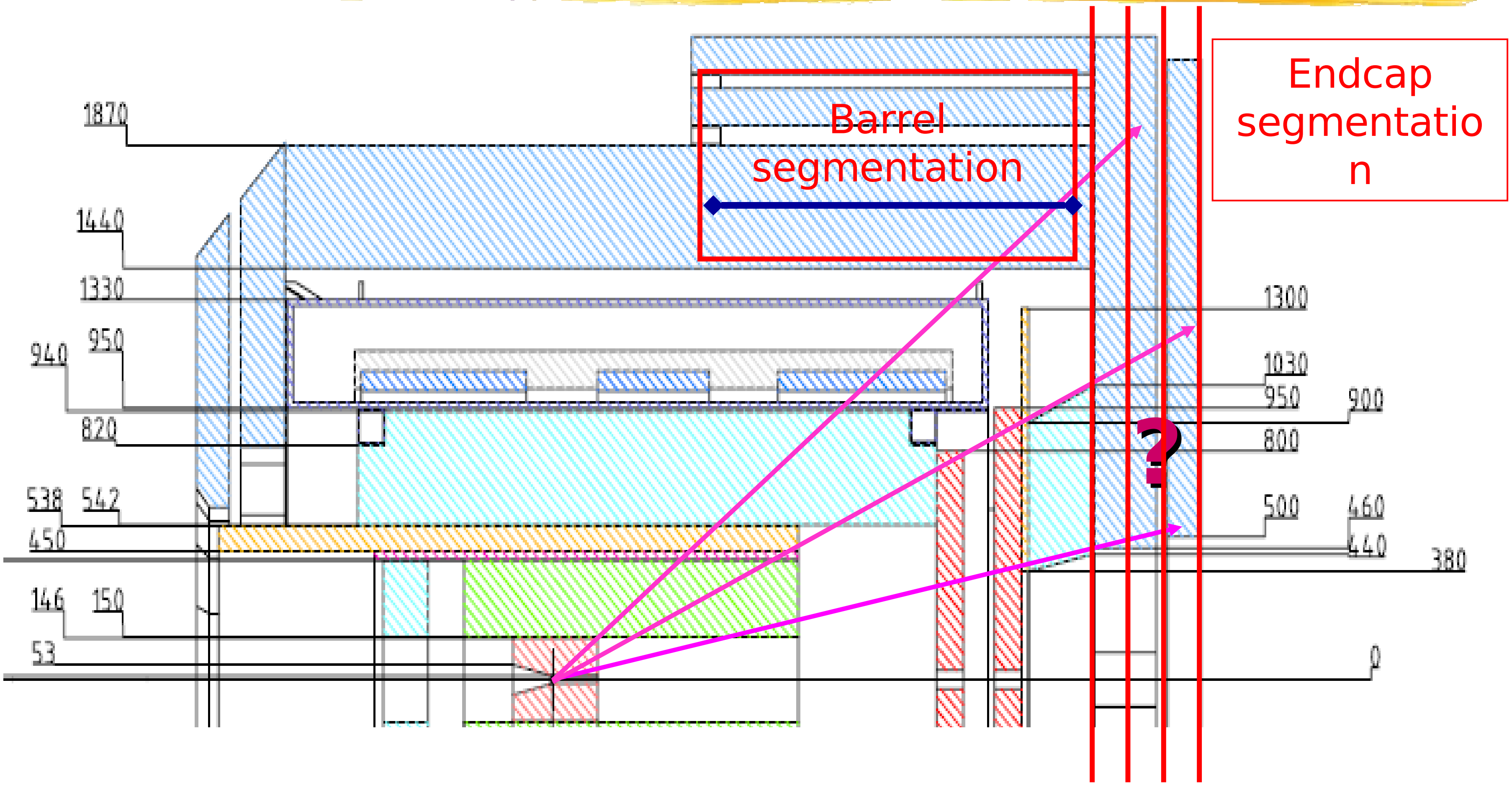


Focus on two $M_{dilepton}$ ranges

Low Mass 1.1<M_d<1.5 GeV

Medium Mass 1.5<M_d<2.5 GeV

Barrel and endcap segmentation



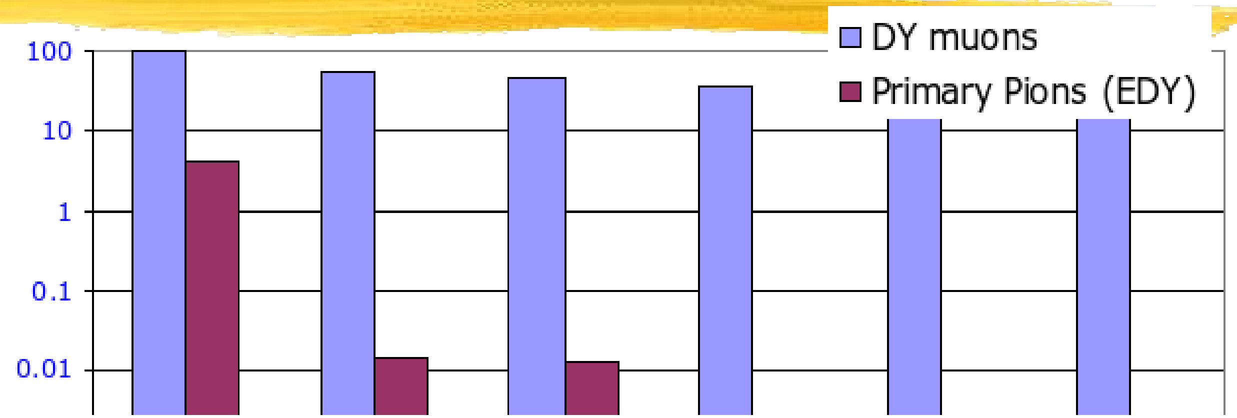
Background: dipions with the dimuon kinematics

Barrel rejection power

rejection power

after 20 cm iron filter

4 10^3



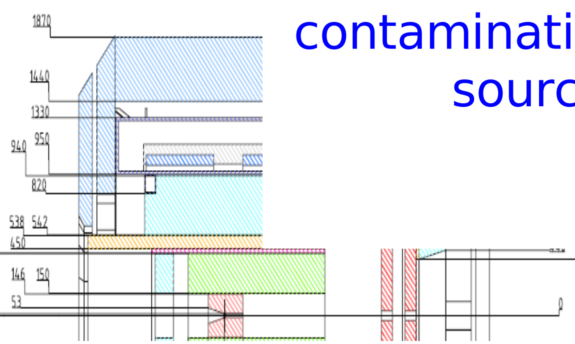
Additional contamination sources

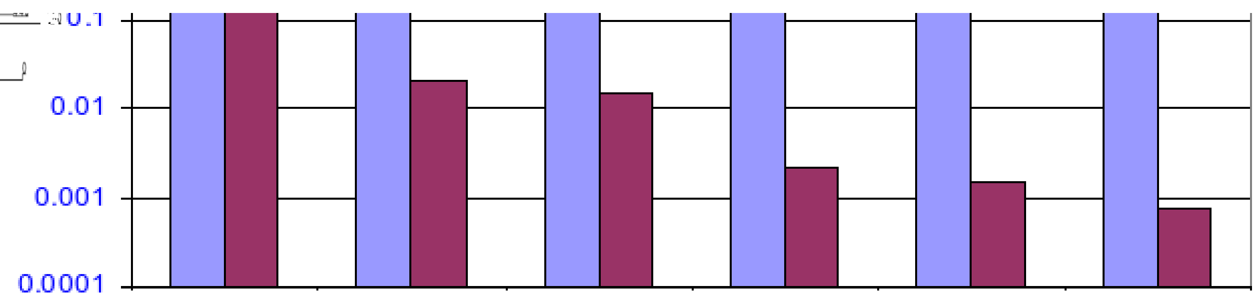
Muons from π decay/primary μ

10^{-2}

Pions from π interaction/primary π

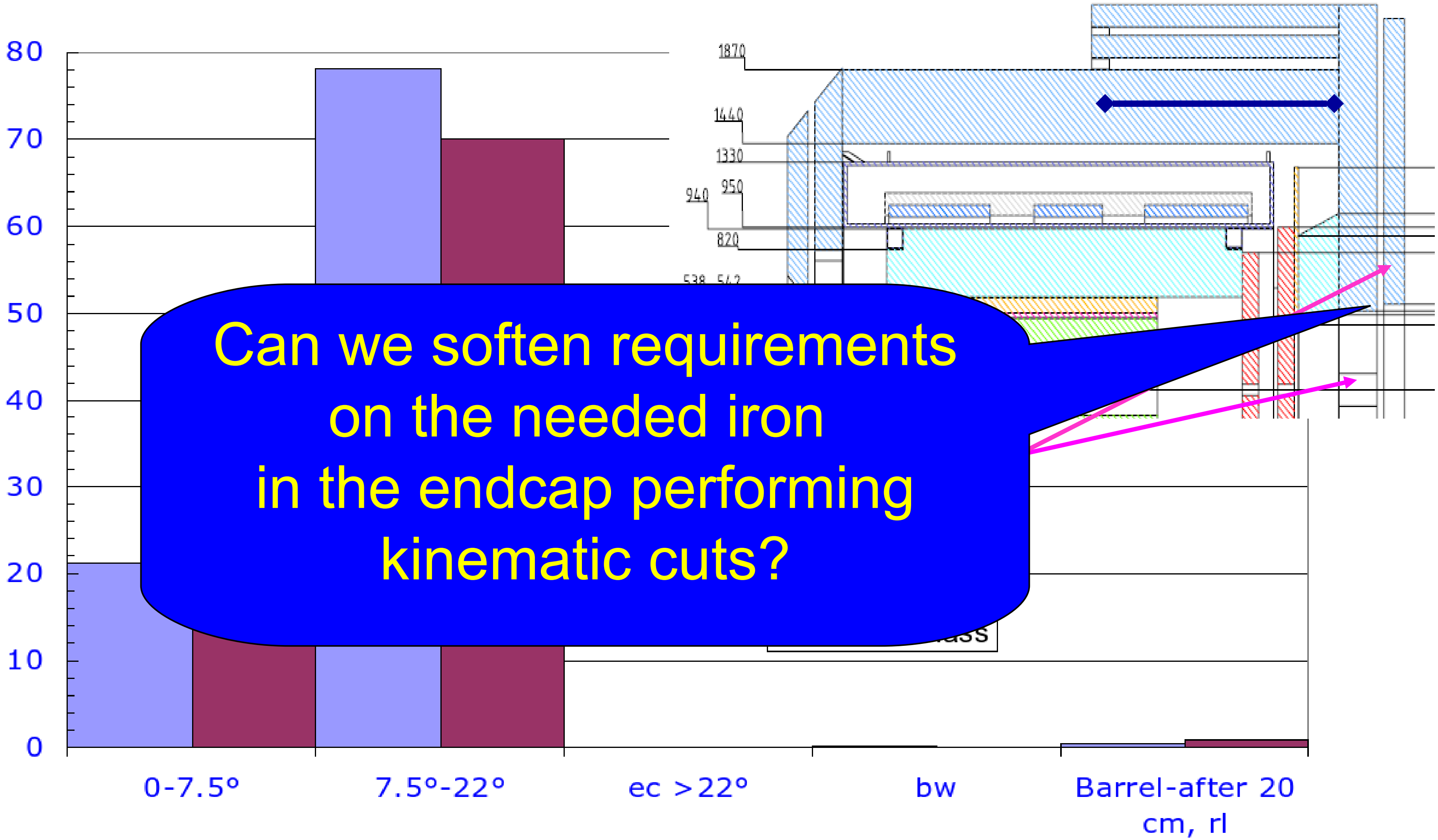
4



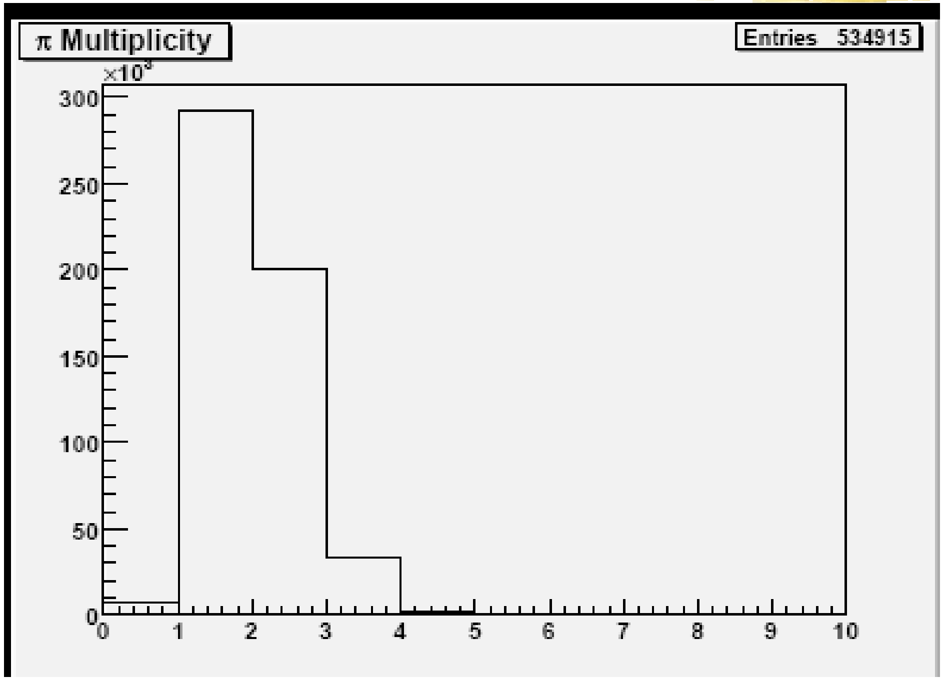


FL= full length
RL=reduced length

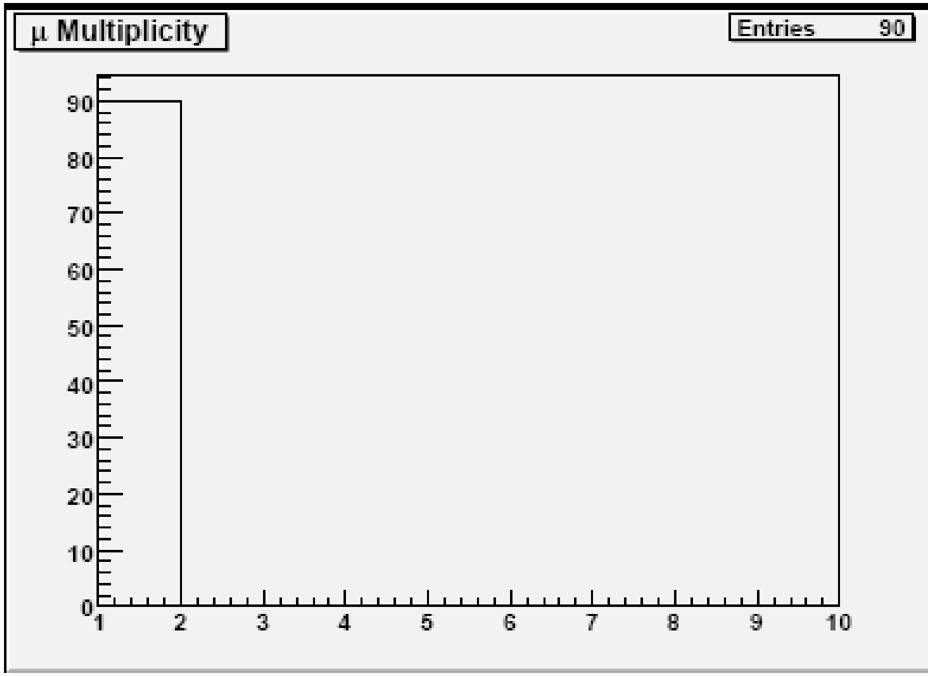
Muons partners of those surviving the barrel



Background simulation with PYTHIA



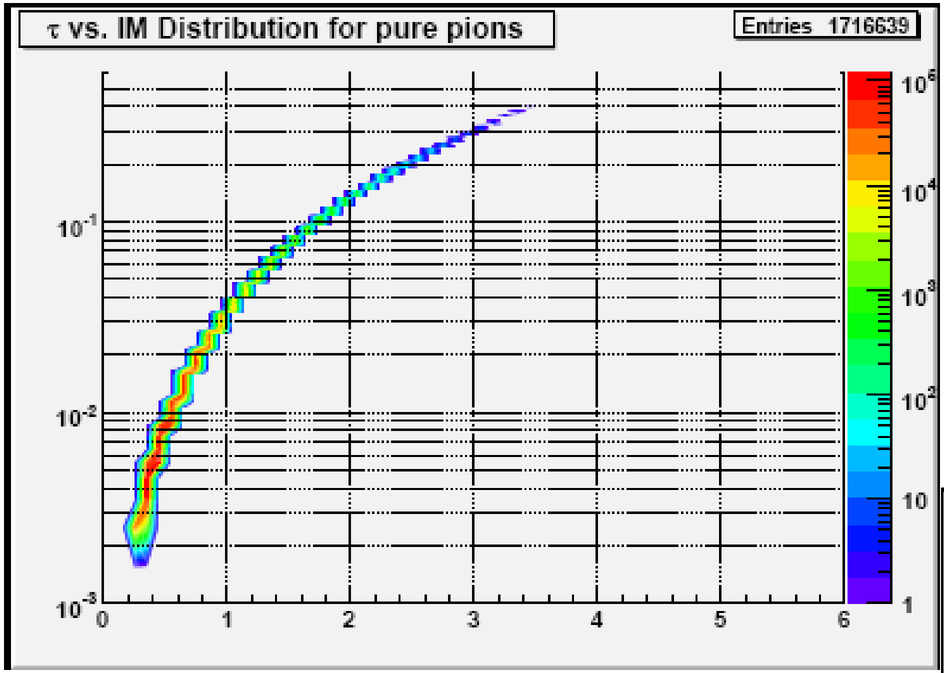
Most (90%) of the events have at most two $\pi^+\pi^-$ couples

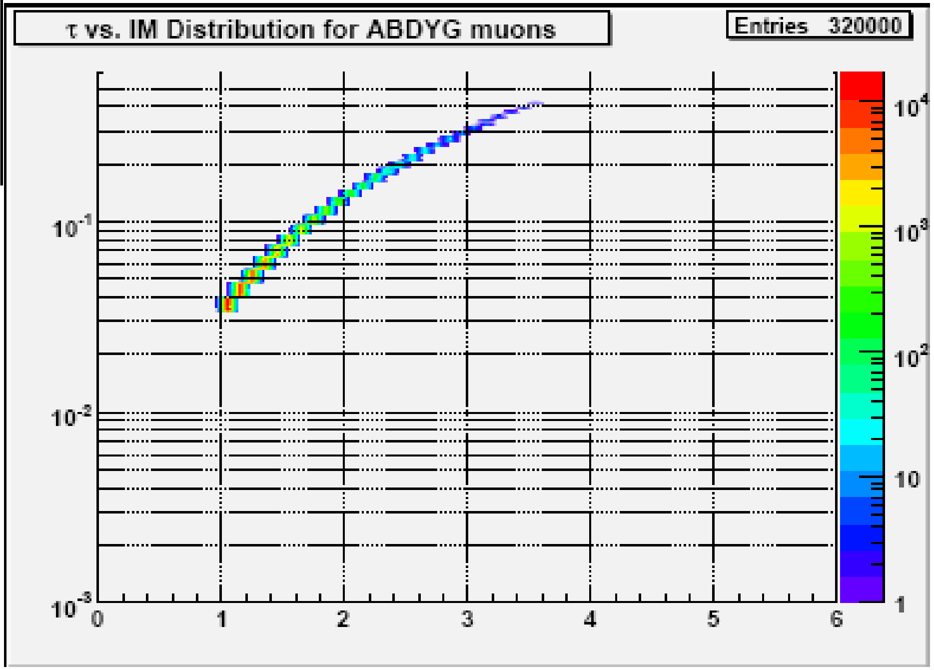


Very few show (at most)

a $\mu^+\mu^-$ couple

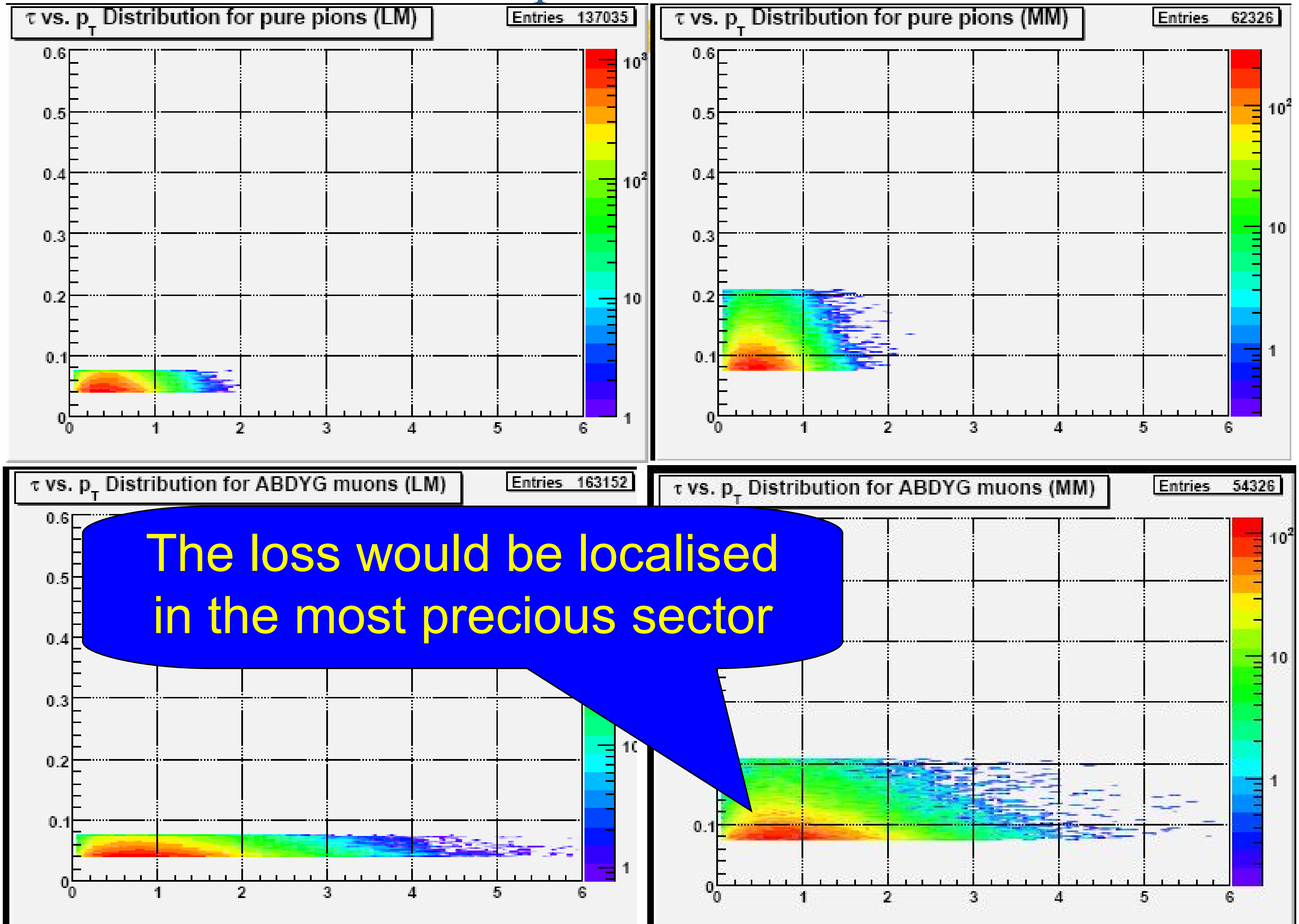
Background and signal kinematics





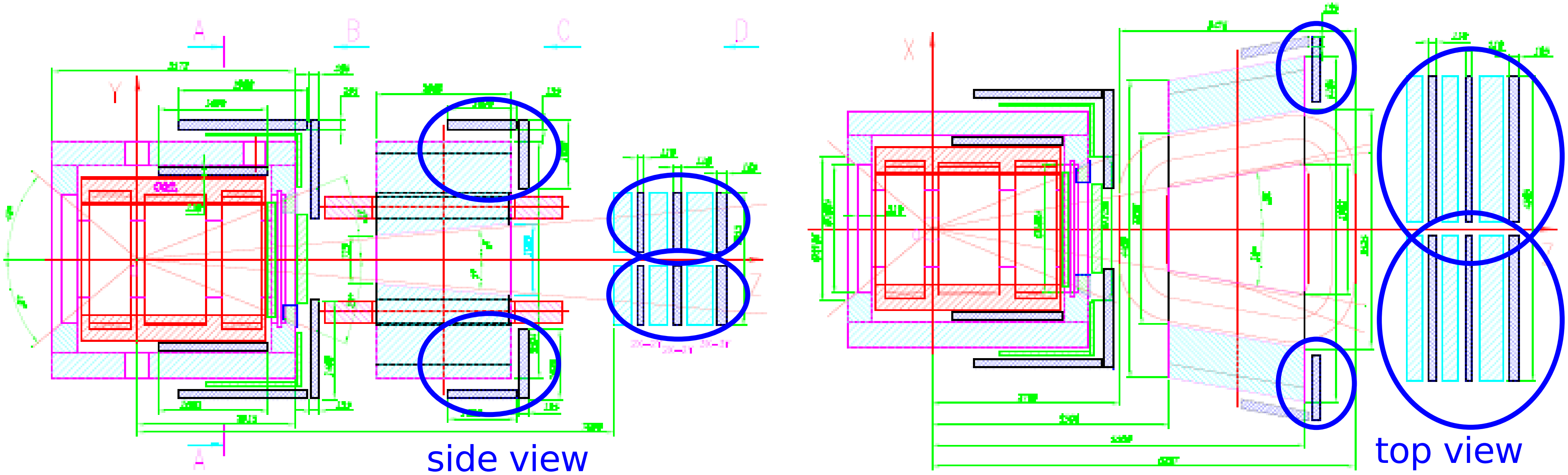
In both cases statistics accumulates in the low IM region

Kinematical cuts are problematic due to statistics loss



Work in progress

- complete background studies simulation
- considering a revised geometry with an enlarged endcap (more Fe-equivalent)
- figuring out requirements in the dipole sector?



Spin physics @ PANDA?

UNPOLARISED DY

$\cos(2\phi)$ asymmetry[1] $\overset{2}{\underset{¿¿}{\Rightarrow}} \; h_1^{¿}(x_{2,}\kappa_{¿}^{2}) \times \bar{h}_1^{¿}(x_1,\kappa_{¿}^{¿}$

Unpolarised cross section

[2] D. Boer et al., Phys. Rev. D60 (1999) 014012.

ANTIPROTONS!!

DY azimuthal asymmetries
not suppressed by nonvalence-like contributions.

DETECTOR STUDIES IN PROGRESS

Question time

THANK YOU!

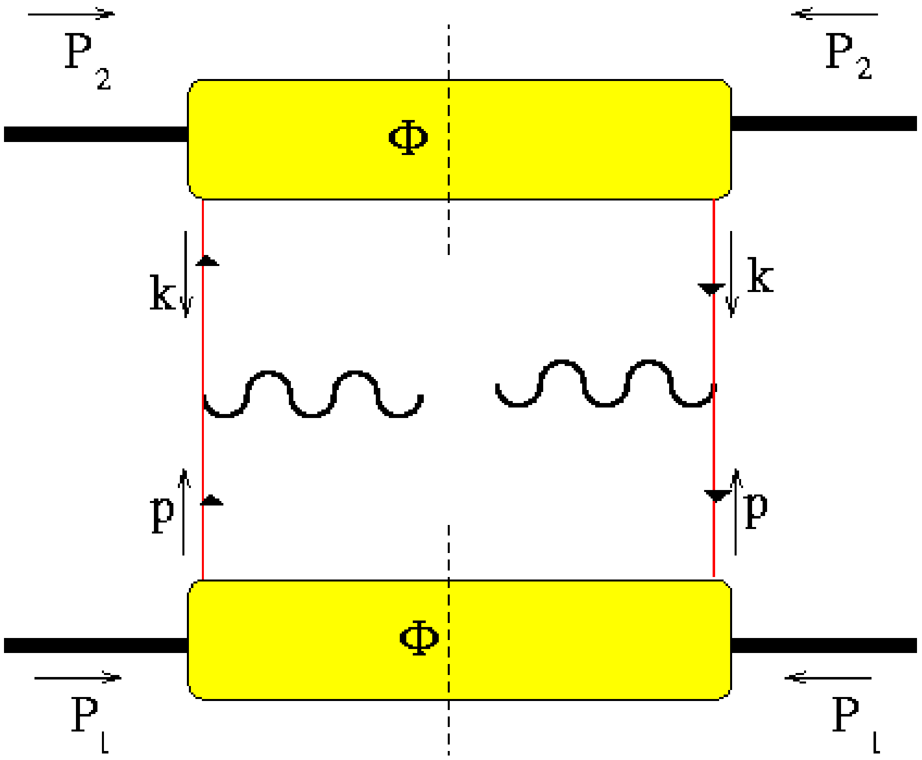
Drell-Yan Asymmetries — $\bar{p}^{\uparrow} p^{\uparrow} \to \mu^{+} \mu^{-} X$

Uncorrelated quark helicities $\Rightarrow$ access chirally-odd functions

TRANSVERSITY

Ideal because:

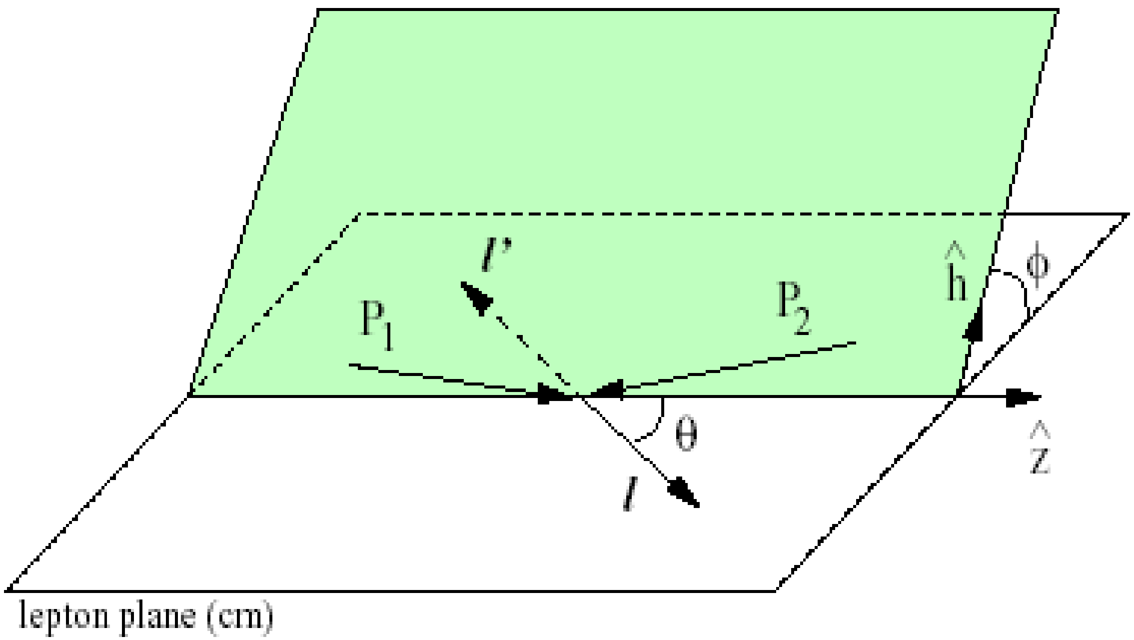
- h_1 not to be unfolded with fragmentation functions
- chirally odd functions not suppressed (like in DIS)



Drell-Yan Asymmetries — $\bar{p}^{\uparrow} p^{\uparrow} \rightarrow \mu^{+} \mu^{-} X$

$$A_{LL} = \frac{\sum_a e_a^2 g_1^a(x_1) g_1^{\bar{a}}(x_2)}{\sum_a e_a^2 f_1^a(x_1) f_1^{\bar{a}}(x_2)} \qquad A_{TT} = \frac{\sin^2\theta \cos 2\varphi}{1+\cos^2\theta} \frac{\sum_a e_a^2 h_1^a(x_1) h_1^{\bar{a}}(x_2)}{\sum_a e_a^2 f_1^a(x_1) f_1^{\bar{a}}(x_2)}$$

$$A_{LT} = \frac{2\sin 2\theta \cos\varphi}{1+\cos^2\theta} \frac{M}{\sqrt{Q^2}} \frac{\sum_a e_a^2 \left(g_1^a(x_1) x_2 g_T^{\bar{a}}(x_2) - x_1 h_L^a(x_1) h_1^{\bar{a}}(x_2) \right)}{\sum_a e_a^2 f_1^a(x_1) f_1^{\bar{a}}(x_2)}$$



To be corrected for:

$$\frac{1}{P_{\vec{p}} f P_{\vec{\bar{p}}}}$$

Collins-Soper frame: [1]Phys. Rev. D16 (1977) 2219.

Drell-Yan Asymmetries — $\bar{p}\, p^{\uparrow} \rightarrow \mu^{+} \mu^{-} X$

$$\frac{1}{\sigma}\frac{d\sigma}{d\Omega} \propto \left(1+\cos^2\theta+\frac{\nu}{2}\sin^2\theta\cos2\varphi+\rho\,|S_{1T}|\sin^2\theta\sin(\varphi-\varphi_{S_1})+\cdots\right)$$

$\lambda \sim 1$, $\mu \sim 0$

$$f_1^{\perp a}(x_1)\, f_1^{a}(x_2) + x_2\, h_1^{a}(x_1)\, h_1^{\perp a}(x_2)$$

$$x_1$$

$$\sum_a e_a^2$$

$$A_T = |S_{1T}|\,\frac{2\sin 2\theta\,\sin(\varphi-\varphi_{S_1})}{1+\cos^2\theta}\,\frac{M}{\sqrt{Q^2}}$$

Even unpolarised $\bar{p}$ beam on polarised p,
or polarised $\bar{p}$ on unpolarised p
are powerful tools
to investigate κ_T dependence of QDF

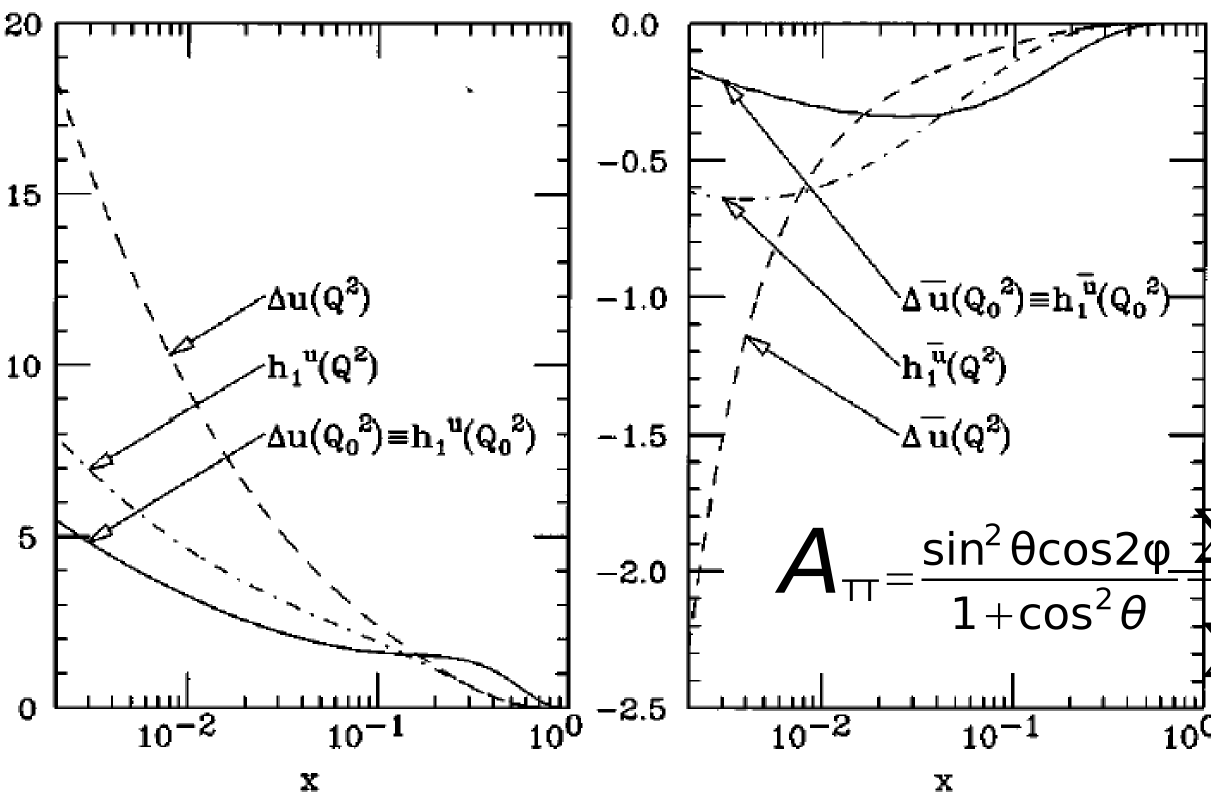
D. Boer et al., Phys. Rev. D60 (1999) 014012.

Drell-Yan Asymmetries — $\bar{p}^{\uparrow} p^{\uparrow} \to \mu^{+}\mu^{-} X$

RHIC energies: $\sqrt{s}=100$ GeV $M^2=100$ ⇨ $\tau \leq 10^{-2}$ ⇨ small x_1 and/or x_2

$h_1^a(x,Q^2)$ evolution much slower[1] than $\Delta q(x,Q^2)$ and $q(x,Q^2)$ at small x

A_{TT} @ RHIC very small, smaller $\sqrt{s}$ would help[1]



$Q_0^2=0.23$ GeV^2

$Q^2=25$ GeV^2

$$A_{TT}=\frac{\sin^2\theta\cos 2\varphi}{1+\cos^2\theta}\,\frac{\sum_a e_a^2 h_1^a(x_1) h_1^{\bar{a}}(x_2)}{\sum_a e_a^2 f_1^a(x_1) f_1^{\bar{a}}(x_2)}$$

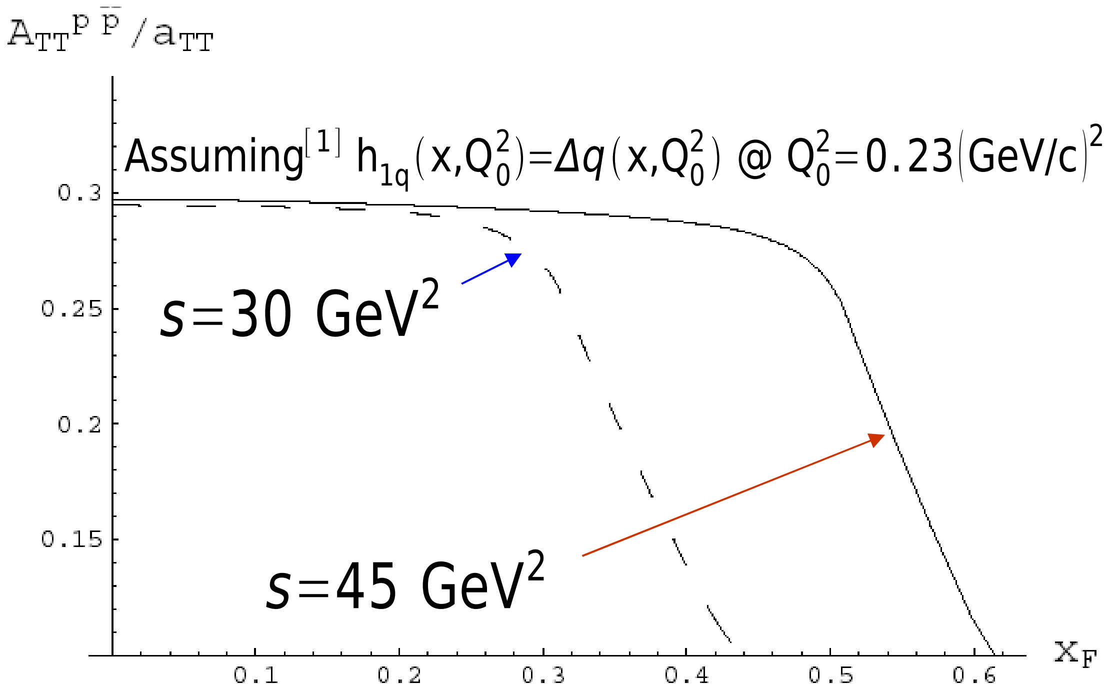
[1]Barone, Colarco and Drago, Phys.Rev. D56 (1997) 527.

Drell-Yan Asymmetries — $\bar{p}^{\uparrow} p^{\uparrow} \rightarrow \mu^{+}\mu^{-} X$

$$A_{TT} = \hat{a}_{TT} \frac{\sum_q e_q^2 \left[h_{1q}^{\bar{p}}(x_1) h_{1\bar{q}}^{p}(x_2) + h_{1\bar{q}}^{\bar{p}}(x_1) h_{1q}^{p}(x_2) \right]}{\sum_q e_q^2 \left[q^{\bar{p}}(x_1) \bar{q}^{p}(x_2) + \bar{q}^{\bar{p}}(x_1) q^{p}(x_2) \right]} \underset{\text{large x}}{¿} \hat{a}_{TT} \frac{\sum_q e_q^2 h_{1q}^{p}(x_1) h_{1q}^{p}(x_2)}{\sum_q e_q^2 q^{p}(x_1) q^{p}(x_2)}$$

A_{TT} still small @ large $\sqrt{s}$ and M^2 due to slow evolution of $h_1^a(x,Q^2)$

Large A_{TT} expected[1] for $\sqrt{s}$ and M^2 not too large and τ not too small



[1]M. Anselmino et al., Phys. Lett. B594 (2004) 97.

HESR: $s_{max} = 30 \div 45\ \mathrm{GeV}^2$

$M^2 \geq M^2_{J/\psi} \longrightarrow \tau \geq 0.3$

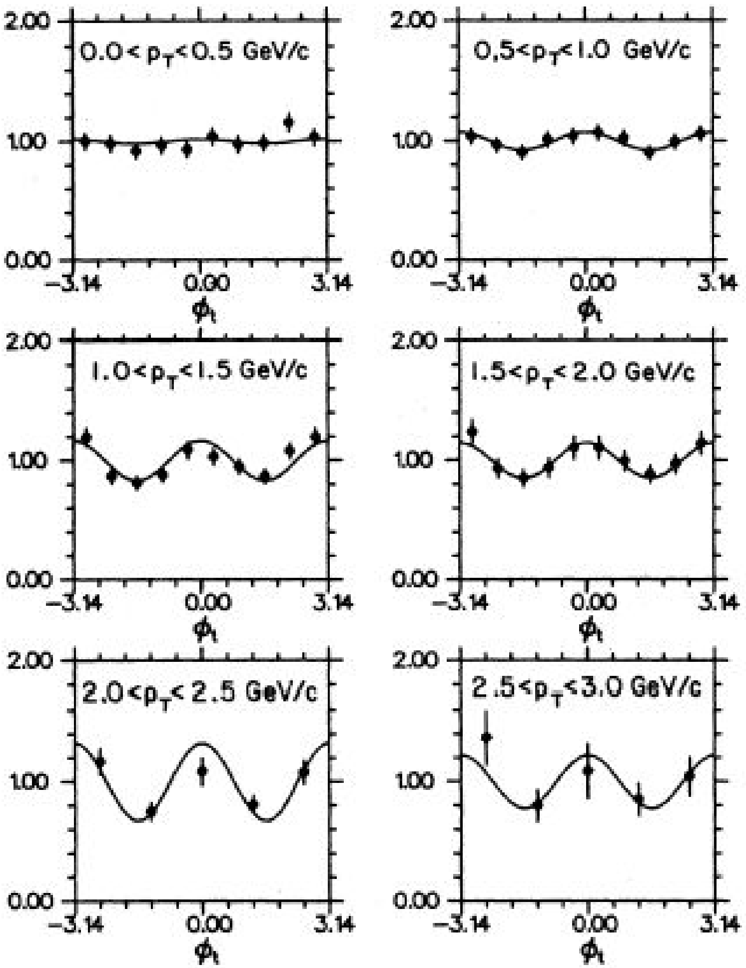
A_{TT} direct access to valence quark h_1

$$h_{1q_V}(x_1) \times h_{1q_V}(x_2)$$

Angular distribution in CS frame

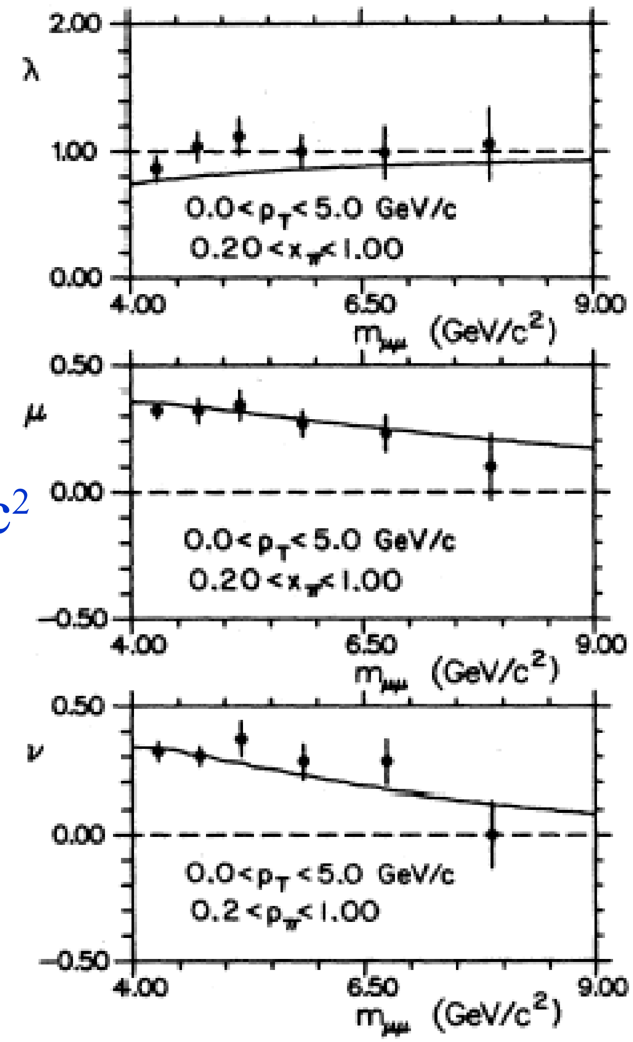
E615 @ Fermilab

$\pi^- N \rightarrow \mu^+\mu^- X$ @ 252 GeV/c



$-0.6 < \cos\vartheta < 0.6$

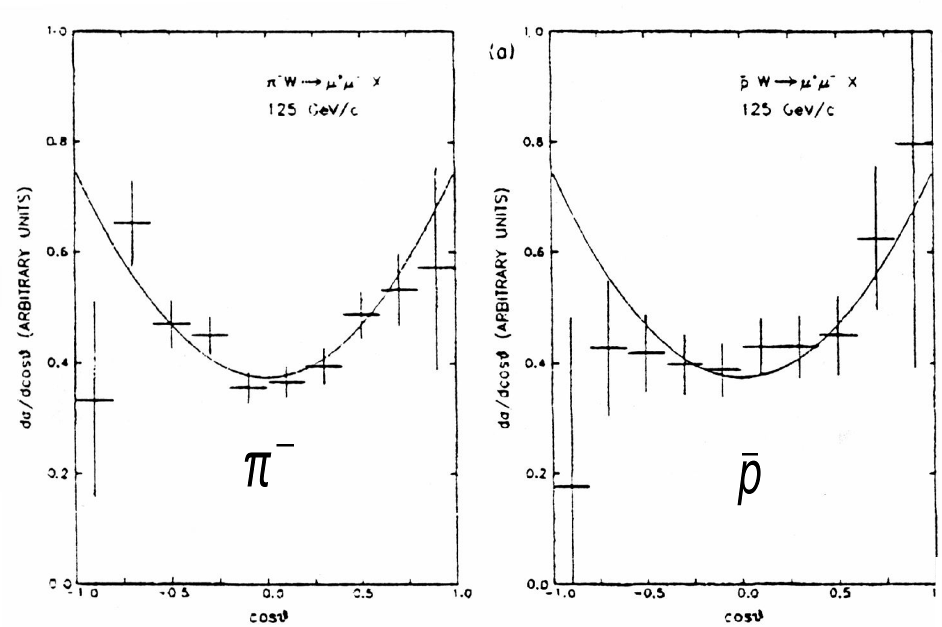
$4 < M < 8.5$ GeV/c^2



Conway et al, Phys. Rev. D39 (1989) 92

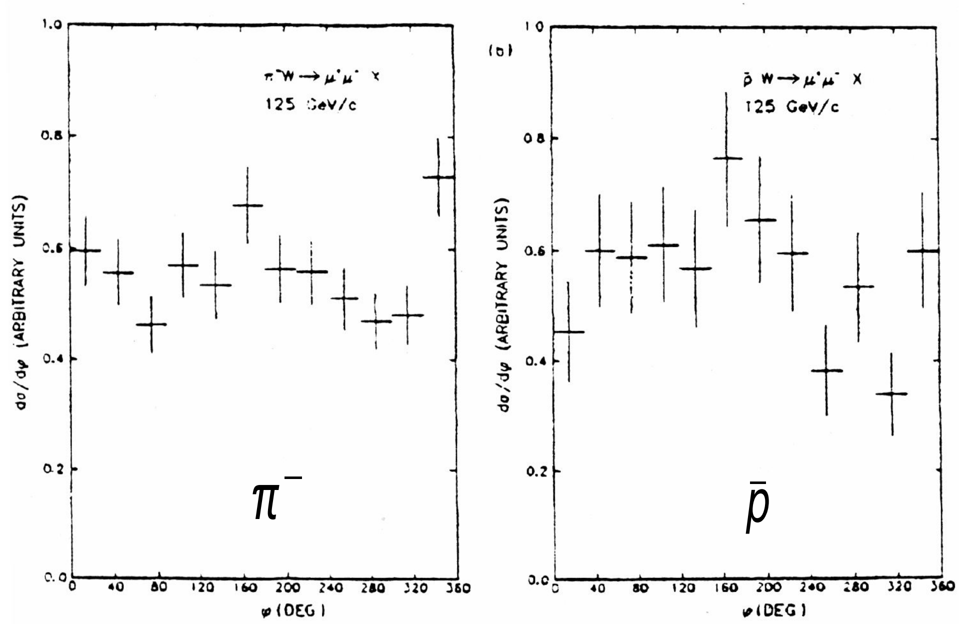
- cut on $\mathbf{P}_T$ selects asymmetry
- 30% asymmetry observed for π^-

Angular distributions for $\bar{p}$ and π^- − π-N, $\bar{p}$N @ 125 GeV/c



- $\dfrac{d\sigma}{d\cos\vartheta}$ vs $\cos\vartheta$

- $\dfrac{d\sigma}{d\phi}$ vs ϕ



E537 @ Fermilab

Anassontzis et al., Phys. Rev. D38 (1988) 1377

Transverse Single Spin Asymmetries

$$A_N = \frac{d\sigma^{\uparrow} - d\sigma^{\downarrow}}{d\sigma \ldots} \quad \ldots {}^{\uparrow} p \rightarrow \pi X$$

- π Production @ l…

  π^+: $A_N > 0$; π^-: A_N … polarisation

  $\sqrt{s}$…

- A_N similar for

  A_N related to funda… …entation

New experiment wi… …kinematical region:

- new data available…
- $A_{N,\ \{\bar{p}p^{\uparrow} \rightarrow \pi X}$ vs $A_{N,\ \{\bar{p}^{\uparrow} p \rightarrow \pi X}$
- DY-SSA (A_T) possible only @RHIC, p↑p-scattering:

  $\sigma^{DY}_{\bar{p}p}$ @ smaller s >> σ^{DY}_{pp} @ large s

E704 Tevatron FNAL 200GeV/c