PHENIX-muon TN

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Brief Notes on Luminosity Monitor and Polarimeter at RHIC

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1 Why Luminosity Monitor and Polarimeter?

Luminosity Monitor

- to obtain absolute cross sections
- to normalize each combination of proton polarizations
  (note: we will measure asymmetry of cross sections),

$$A_{LL} = \frac{1}{P_B^2}\frac{\sigma(++) - \sigma(+-)}{\sigma(++) + \sigma(+-)} \tag{1}$$

- to compare the runs with different conditions, e.g. low luminosity for J/ψ and ψ' and high luminosity for Υ and Υ'.
- to have your own data points in Particle Data Book (pp total cross section at $\sqrt{s} > 63$ GeV)

Polarimeter

- to obtain Δq, $\Delta\bar{q}$, ΔG, Δq_T, ...

$$A_{LL}(pp \to \mu^+\mu^- X) \approx \frac{1}{P_B^2}\frac{\Delta q}{q}\frac{\Delta\bar{q}}{\bar{q}} \tag{2}$$

- to define polarization axis

$$A_{TT}(pp \to \mu^+\mu^- X) = \frac{\sin^2\theta\cos 2\phi}{1+\cos^2\theta}\frac{\Sigma_a e_a^2 \Delta q_T^a(x_1)\Delta\bar{q}_T^a(x_2) + (2 \leftrightarrow 1)}{\Sigma_a e_a^2 q^a(x_1)\bar{q}^a(x_2) + (2 \leftrightarrow 1)} \tag{3}$$

- to compare with polarized-DIS experiment

2 Luminosity Monitor

reference
F. Abe *et al.*, PR **D50** (1994) 5550;
F. Abe *et al.*, PR **D50** (1994) 5518.

Measured the antiproton-proton total cross-section at $\sqrt{s} = 546$ and 1800 GeV by *luminosity independent method*

$$\sigma_T = \frac{1}{L}(R_{el} + R_{in}) \tag{4}$$

...from optical theorem

$$\sigma_T^2 = \frac{16\pi(\hbar c)^2}{1+\rho^2}\frac{1}{L}\frac{dR_{el}}{dt}\mid_{t=0} \tag{5}$$

σ_T	:	total cross section
L	:	machine luminosity
R_{el}	:	elastic rate
R_{in}	:	inelastic rate
ρ	:	real to imaginary ratio of forward elastic amplitude
t	:	four-momentum transfer squared

$$\sigma_T = \frac{16\pi(\hbar c)^2}{1+\rho^2}\frac{dR_{el}/dt\mid_{t=0}}{R_{el}+R_{in}} \tag{6}$$

"*...At present, only this method provides a precise measurement of the Tevatron luminosity and of the total cross section.* "

Detector

Operating Condition

- Luminosity Run

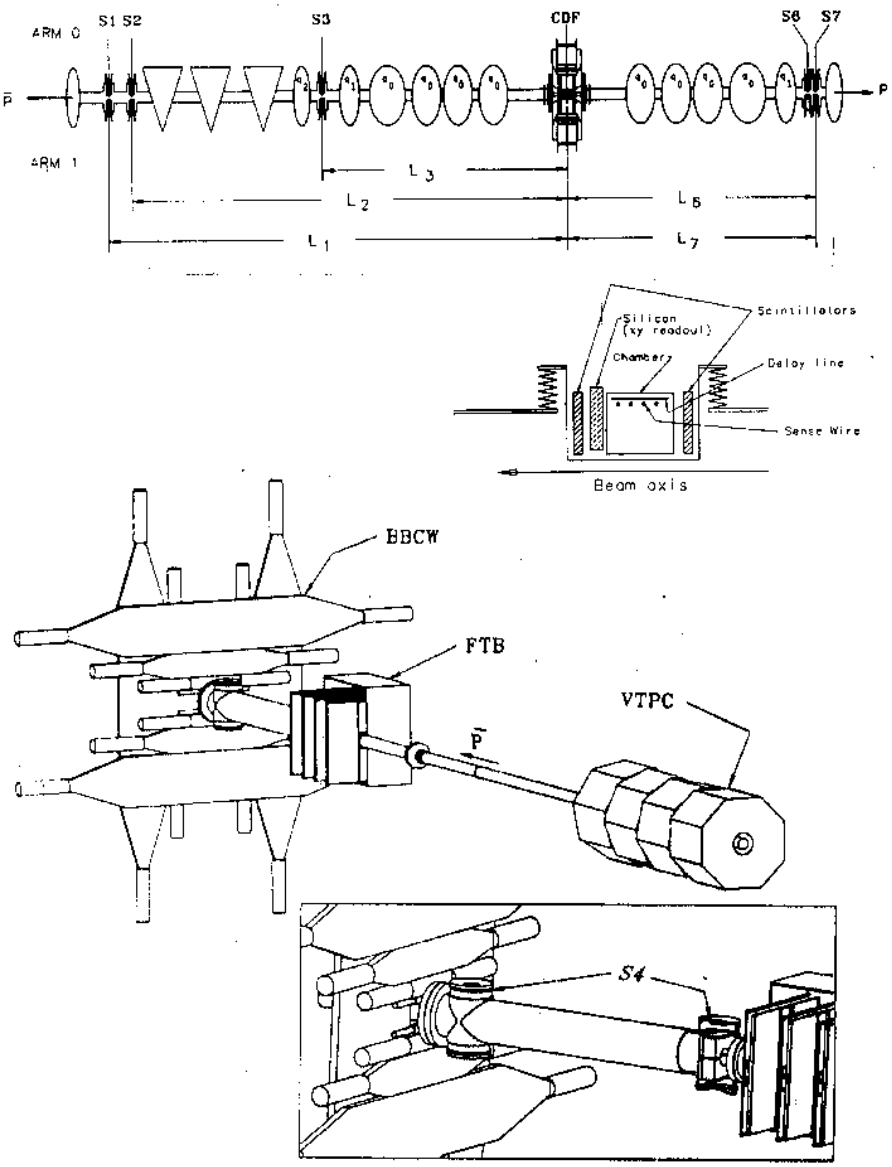
$$\begin{aligned} \mathcal{L} &= 3.2 \times 10^{27}\mathrm{cm}^{-2}\mathrm{sec}^{-1} \quad \sqrt{s} = 546 \text{ GeV} \\ &= 1.9 \times 10^{26}\mathrm{cm}^{-2}\mathrm{sec}^{-1} \quad \sqrt{s} = 1800 \text{ GeV} \end{aligned}$$

- Physics Run

$$\mathcal{L} = 1 - 10 \times 10^{30}\mathrm{cm}^{-2}\mathrm{sec}^{-1} \quad \sqrt{s} = 1800 \text{ GeV}$$

detector I (FTB) only in luminosity runs	
coverage	$0.45° < \theta < 2.56°$ ($3.8 < \eta < 5.5$)
detector	4-drift chambers (x-and y-planes, delay line)
drift cell	4 cm × 36 cm
single hit resolution	700 μm (2.0 cm with delay line)
two-hit resolution	4.0 mm (12.0 cm with delay line)
detector II (S4) only in luminosity runs	
coverage	$0.14° < \theta$
detector	drift chamber backed by trigger scintillation counter
dimension	7 cm×7 cm with a 1.2 cm-radius hole
single hit resolution	200 μm (420 μm with delay line)
two-track resolution	4 mm (2 cm with delay line)
detector III (S1-3,S6-7) only in luminosity runs	
coverage	$0.008° < \theta$ (4 mm at 30 m from interaction point)
detector	drift chamber + silicon detector + trigger scintillation counter
single hit resolution	110 μm(DC),50 μm(SSD)
two-track resolution	3 mm (DC) 1.0 mm(SSD)
vertex detector (VTPC)	
coverage	$3.5° < \theta < 176.5°$
single hit resolution	200-500 μm in rz-plane
two-track resolution	6 mm in rz-plane
scintillation detector (BBCW)	
coverage	$0.32° < \theta < 4.47°$

CDF (*from* PR **D50** (1994) 5518, ibid. 5550.)



RHIC

- If the total cross section is known, we only have to measure $(R_{el} + R_{in})$.
- Proposal to Measure Total and Elastic pp Cross Sections at RHIC.
  (see `www` or `/p2hp3/usr2/saito/doc/pp2pp_prop.ps.gz`)

Can we measure $(R_{el} + R_{in})$ with Baseline Detectors?

MVD + BB array $\rightarrow 2^\circ < \theta < 178^\circ$
0.32°(CDF coverage) $\rightarrow$ 5.0 cm @ 10 m

- In our case of Physics Run

$$\begin{aligned} \mathcal{L} &= 2.0 \times 10^{32}\mathrm{cm}^{-2}\mathrm{sec}^{-1} \quad p+p \quad \text{maximum} \\ &= 2.0 \times 10^{27}\mathrm{cm}^{-2}\mathrm{sec}^{-1} \quad \mathrm{Au}+\mathrm{Au} \quad \text{maximum} \\ &= 1.5 \times 10^{29}\mathrm{cm}^{-2}\mathrm{sec}^{-1} \quad p+\mathrm{Au} \quad \text{maximum} \end{aligned}$$

reaction	σ_{tot}	rate
$p+p$	50 mb	1.0×10^7 Hz
Au+Au	7000 mb	1.4×10^4 Hz
p+Au	1700 mb	2.6×10^5 Hz

MVD + BB array + SCIFI to go to 0.32°????

3 Polarimeter

There are two techniques.

- Primakoff Polarimeter
- Coulomb-Nuclear-Interference (CNI) Polarimeter

Primakoff Polarimeter

Measure asymmetry in the process

$$p + \mathrm{Z} \ \rightarrow \Delta/N^* \rightarrow p + \pi^0 + \mathrm{Z}$$

Z:high-Z nucleus

Fundamental process is considered as

$$p + \gamma^* \rightarrow \Delta/N^* \rightarrow p + \pi^0$$

The absolute polarization of the proton beam can be obtained by comparing the measured asymmetry with the asymmetry for photo-production process measured at low energy ($\sim$ 700 MeV).

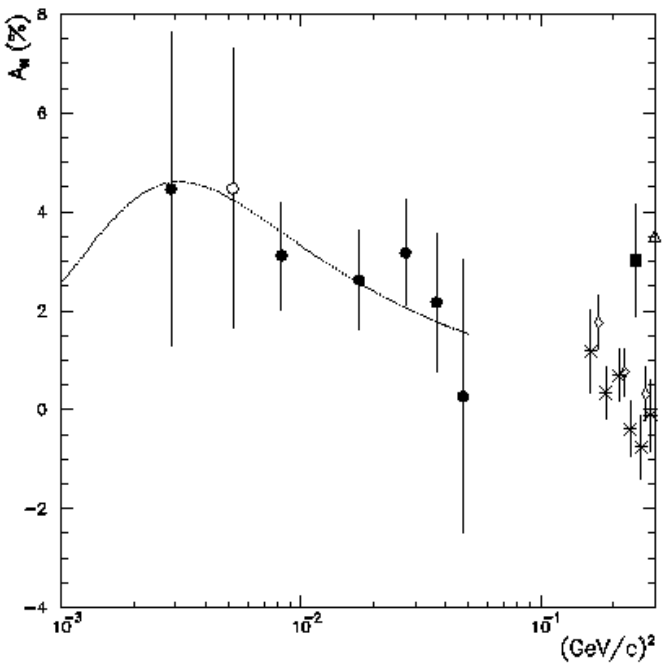
- Could be applicable to pA collision

reference

B.E. Bonner *et al.*, PRL 61 (1988) 1918.
M. Margolis and G.H. Thomas, in AIP Conf. Proc. No. 42, High Energy Polarized Proton Beams, Ann Arbor, 1977, eds. A.D. Krisch and A.J. Salthouse. (AIP, New York,1978) p. 173; G.Fäldt *et al.*, NP **B41** (1972) 125.

CNI method

Measure asymmetry for pp elastic scattering in Coulomb-nuclear-interference region, $1.5\times10^{-3} < |t| < 5.0^{-2}$ (GeV/c)^2. The asymmetry is theoretically calculated to be 4.6% at $|t| = 3.12 \times 10^{-3}$ (GeV/c)^2. The absolute polarization was determined comparing the asymmetry with the theoretical calculation.



reference

N. Akchurin *et al.*, PR **D48** (1993) 3026.

B.Z. Kopeliovich and LI Lapidus, Yad. Fiz. **19** (1974) 218 [Sov. J. Nucl. Phys. **19** (1974) 114].

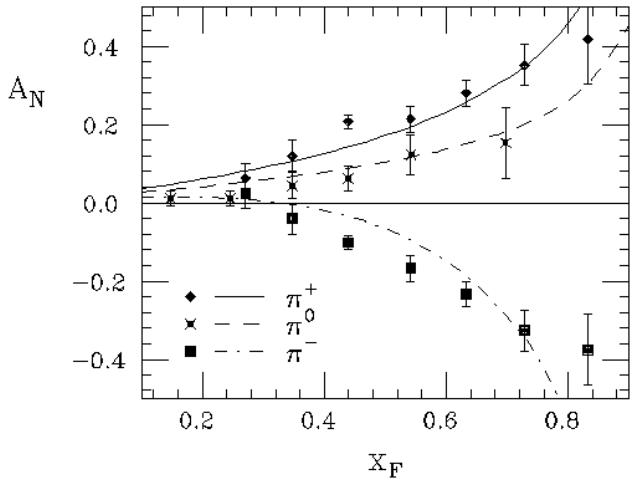
Measurement - FNAL-E704

Polarized proton/antiproton beam of 185 to 200 GeV/c.

	Polarization
Monte Carlo Simulation	46± 1.9 %
Primakoff Polarimeter	40±9±15%
CNI Polarimeter	45±17%

Relative Measurement, $A_N(pp \to \pi X)$

Large asymmetry at large-x_F in pp collisions at $\sqrt{s} = 19.4$ GeV
D.L. Adams *et al.*, PL **B264** (1991) 462,
D.L. Adams *et al.*, ZP **C56** (1992) 181



Theoretical curves by Anselmino, Bogolione, and Murgia.
(see `hep-ph@xxx.lanl.gov 9410382`)