Update about the estimated precision of the polarization measurements using π^0 in the SPD ECAL endcaps

Extraction of A_N

$p^{\uparrow} + p \rightarrow \boldsymbol{\pi^0} + X \qquad \phi = 2\pi$

The cross section of hadron production in polarized $p^{\uparrow} + p$ collisions, is modified in azimuth.

$$\frac{d\sigma}{d\phi} = \frac{d\sigma}{d\phi_0}(1 + \underbrace{P \cdot A_{\mathrm{N}} \cdot \cos\phi}_{\text{Azimuthal cosine modulation}})$$

$$N_{\boldsymbol{\pi^0}}(\phi) = A(1 + B\cos\phi)$$

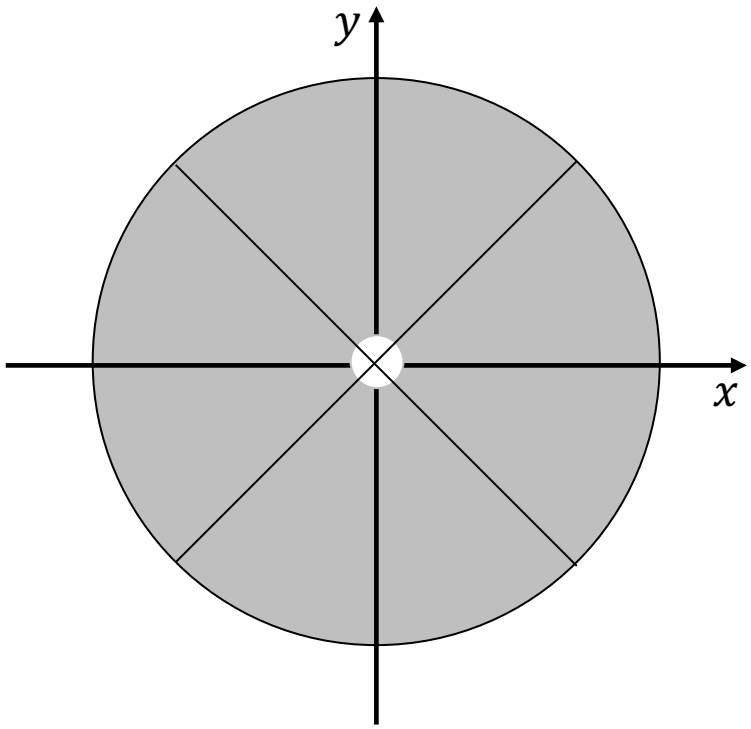
$$A_N = \frac{B}{P}$$

$N_{\boldsymbol{\pi^0}}(\phi)$: Yield of π^0

P: Beam polarization

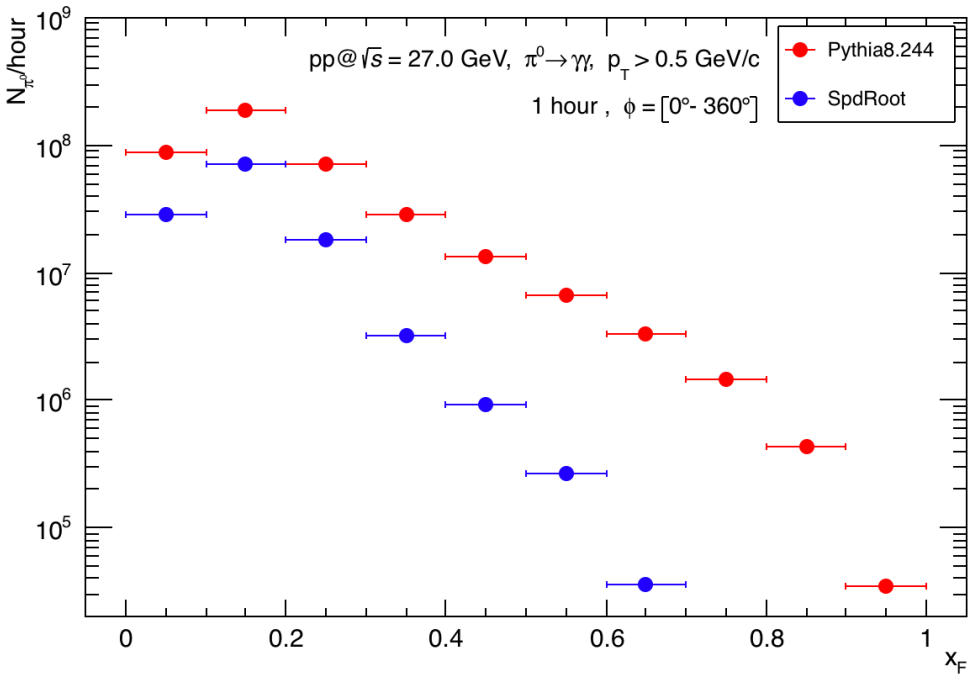
- P ~ 0.7 was assumed

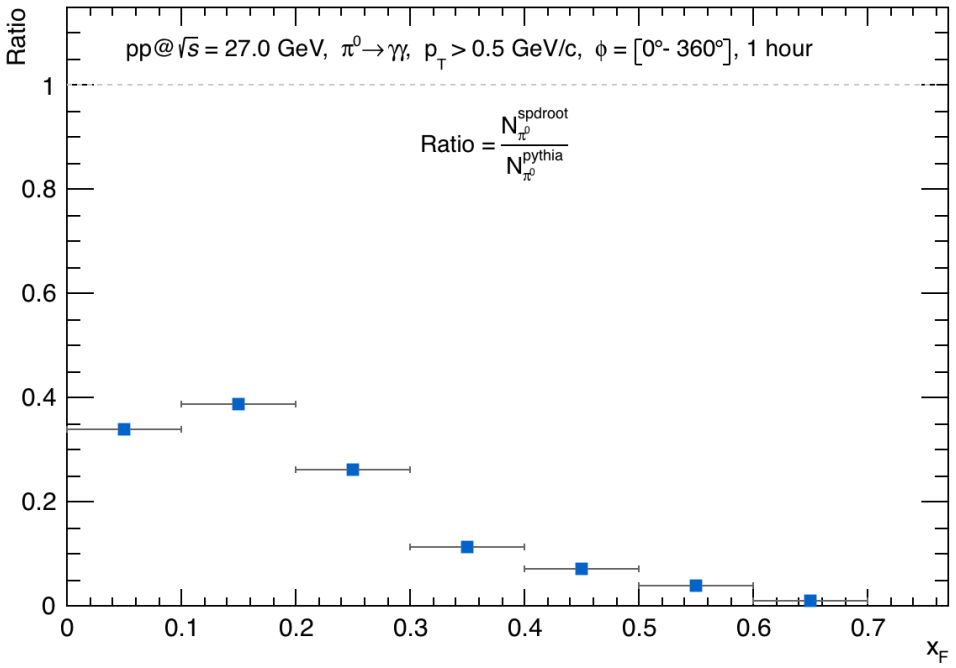
8 azimuthal bins



- The spin dependent π^0 yields for each bin are extracted from the invariant mass spectra in different x_{F} sub-ranges for each ϕ bin.
- The invariant mass was fitted with a **polynomial** function for the background and a **normalized Gaussian** distribution representing the signal peak.

Estimation of π^0 yield in the ECAL endcaps





Expected in 1 hour at a reaction rate $4 \cdot 10^6 s^{-1}$

Expected number of π^0 in 1 hour assuming the SPD reaction rate of $4 \cdot 10^6 s^{-1}$, calculated from the invariant mass spectra ($\pi^0 \to \gamma\gamma$) in $0° < \phi < 360°$:

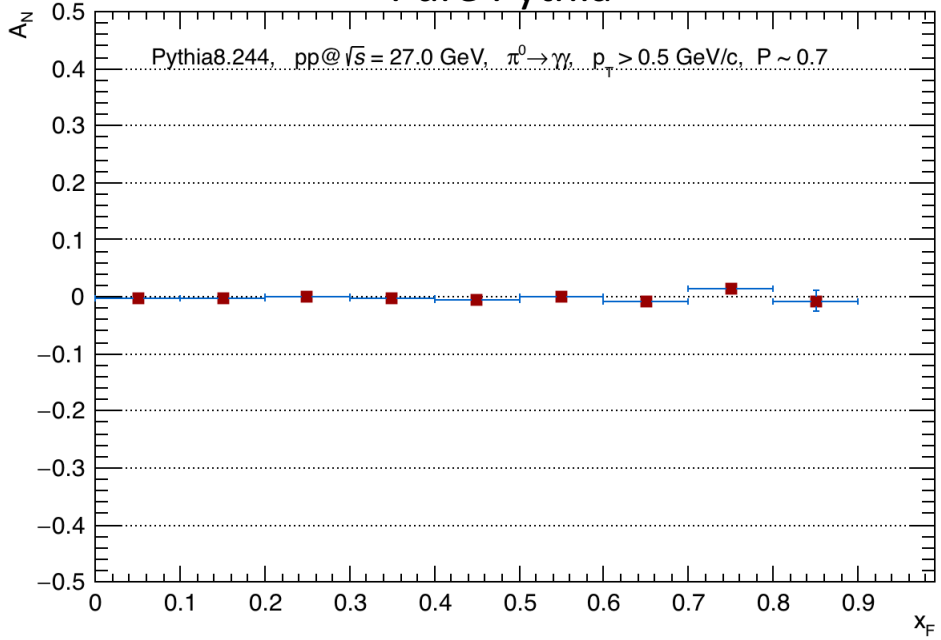
$$N_{\pi^0}(pythia) = (4.0131 \cdot 10^8 \pm 46987)\ \text{hour}^{-1}$$

$$N_{\pi^0}(spdroot) = (1.2337 \cdot 10^8 \pm 21907)\ \text{hour}^{-1}$$

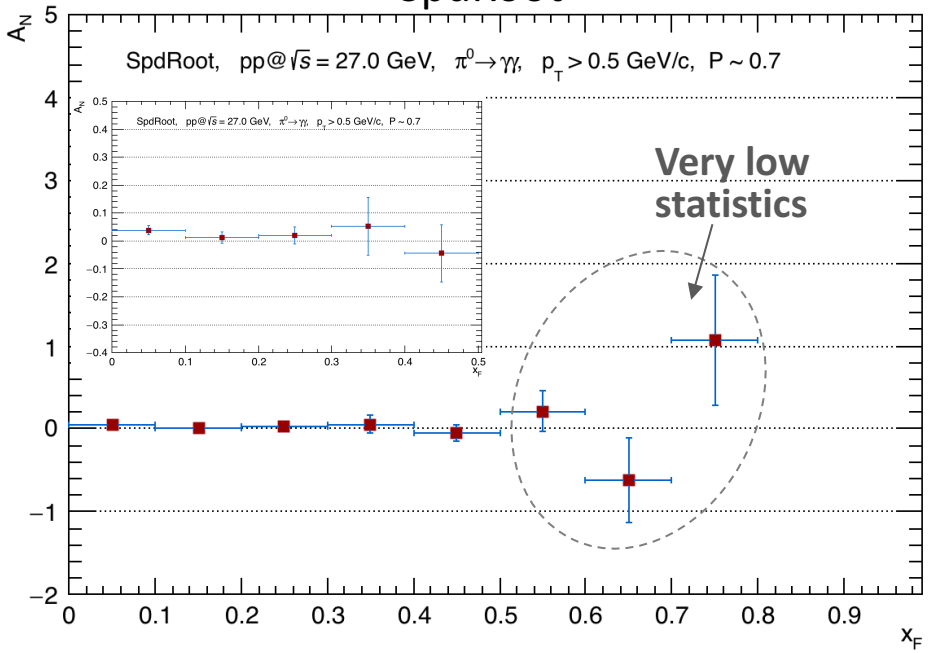
x_F	N_{π^0}(pythia)	N_{π^0}(spdroot)
0.0 – 0.1	8.71623e+07 ± 9336	2.88889e+07 ± 5374
0.1 – 0.2	1.89277e+08 ± 13757	7.17679e+07 ± 8471
0.2 – 0.3	7.05884e+07 ± 8401	1.81456e+07 ± 4259
0.3 – 0.4	2.90411e+07 ± 5388	3.26321e+06 ± 1806
0.4 – 0.5	1.34162e+07 ± 3662	9.34335e+05 ± 966
0.5 – 0.6	6.60482e+06 ± 2569	2.62667e+05 ± 512
0.6 – 0.7	3.27958e+06 ± 1810	3.56159e+04 ± 188
0.7 – 0.8	1.46884e+06 ± 1211	7.41998e+04 ± 272
0.8 – 0.9	4.37768e+05 ±661	2967.99e ± 54
0.9 – 1.0	3.43149e+04 ± 185	-

A_N in the ECAL endcaps

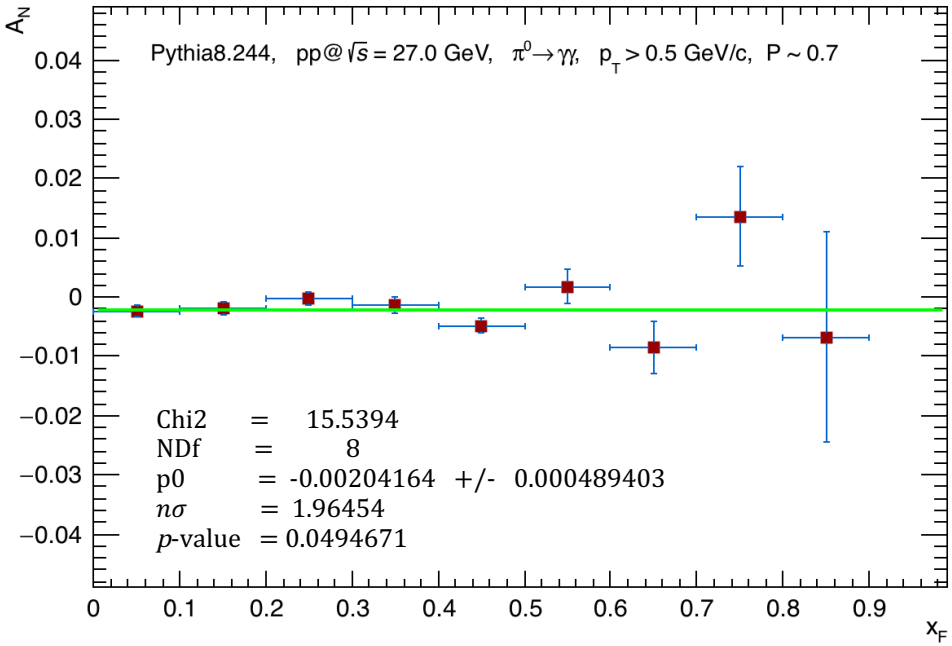
Pure Pythia



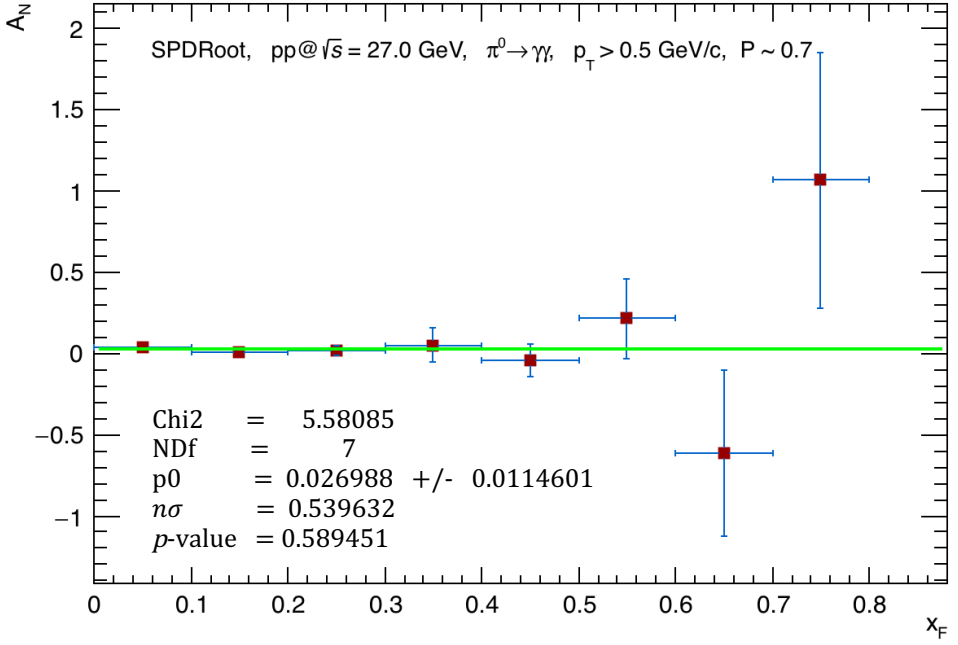
SpdRoot



Pure Pythia



SpdRoot



Relative error for A_N

By using the measured A_N from the E704 experiment at $\sqrt{s} = 19.4$ GeV, we can estimate the relative error of $\frac{\Delta A_N}{A_N}$ *vs.* x_F

$$\frac{\Delta A_N}{A_N} \sim \frac{\Delta P}{P}$$

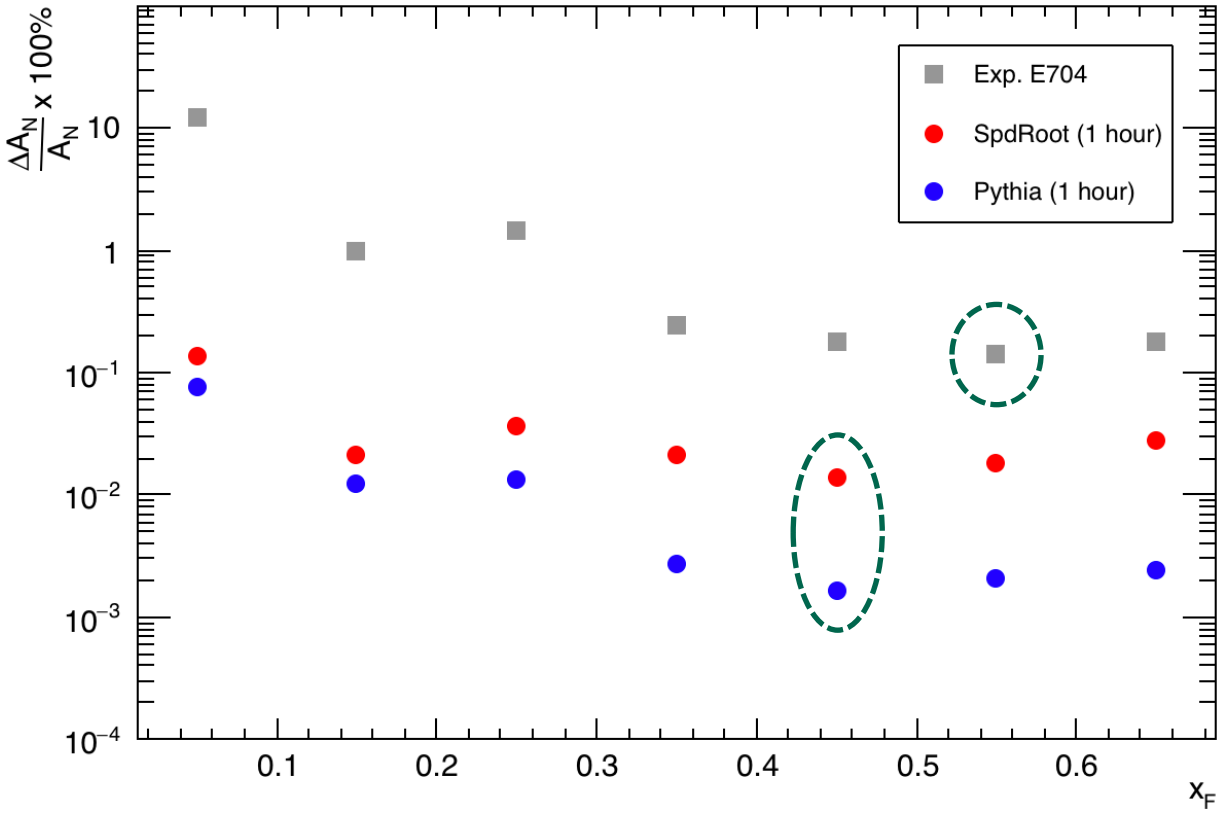
ΔA_N scaled to 1 hour of data taking (Pythia and SPDRoot)

$\frac{\Delta A_N}{A_N}$ → SpdRoot

$\frac{\Delta A_N}{A_N}$ → E704

$\frac{\Delta A_N}{A_N}$ → Pythia

$\frac{\Delta A_N}{A_N}$ → E704



Relative of A_N error estimated for 1 hour

x_F	$\frac{\Delta A_N}{A_N}$ (%)	
	SpdRoot (1h)	Pythia (1h)
0.0 -0.1	13.41	7.54
0.1 -0.2	2.10	1.22
0.2 -0.3	3.62	1.32
0.3 -0.4	2.12	0.28
0.4 -0.5	1.36	0.16
0.5 -0.6	1.81	0.21
0.6 -0.7	2.83	0.23

The determination of the polarization is expected to be precise for $0.4 < x_F < 0.6$.

Estimated relative error of the Polarization

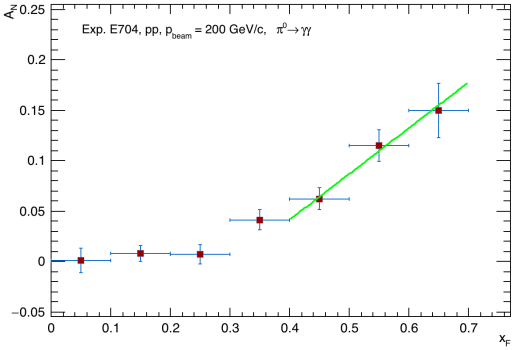
$$\frac{\Delta A_N}{A_N} \sim \frac{\Delta P}{P}$$

Raw asymmetry:

$P \cdot A_N \cdot \cos\phi = \epsilon(\phi) \Leftrightarrow \epsilon(\phi) = \frac{N^{\uparrow}(\phi) - N^{\downarrow}(\phi)}{N^{\uparrow}(\phi) + N^{\downarrow}(\phi)}$

$P \cdot A_N \sim \epsilon$

$$\sigma_{Pol} = \frac{1}{\sqrt{\sum_i \left(\frac{1}{\sigma^2_{A_{N_i}}}\right)}} \Rightarrow \frac{\Delta P}{P} = \frac{1}{\sqrt{\sum_i \left(\frac{A_{N_i}}{\Delta A_{N_i}}\right)^2}} \Leftarrow \langle P \rangle = \frac{\sum_{i=1}^{n} w_i P_i}{\sum_{i=1}^{n} w_i}, \quad w_i = \left(\frac{1}{\Delta P_i}\right)^2$$



Taking the last 3 points ($0.4 \leq x_F \leq 0.7$):

$\frac{\Delta P}{P} \approx 0.010$ 1.0% (MC - SPDRoot)

$\frac{\Delta P}{P} \approx 0.0011$ 0.1% (MC - Pythia)

$\frac{\Delta P}{P} \approx 0.0935$ 9.3% (Experiment E704)

Taking the last 4 points ($0.3 \leq x_F \leq 0.7$):

$\frac{\Delta P}{P} \approx 0.0091$ 0.9% (MC - SPDRoot)

$\frac{\Delta P}{P} \approx 0.0010$ 0.1% (MC - Pythia)

$\frac{\Delta P}{P} \approx 0.0873$ 8.7% (Experiment E704)

*The error of the beam polarization in the experiment **E704** is estimated in **10%**, as reported in FERMILAB-Pub-91/15-E[E581,E704]*

1 hour

We might define a beam polarization in SPD endcaps with a precision $\Longrightarrow \frac{\Delta P}{P} \approx 1\%$

- The determination of the polarization is expected to be precise for $0.4 < x_F < 0.6$.

- The precision for the the beam polarization in one hour is estimated in $\sim 1\%$ from SPDRoot simulations.

- From the asymmetry determination, a polarization uncertainty $\frac{\Delta P}{P} \sim 5\%$ **can be predicted for 2 minutes**.