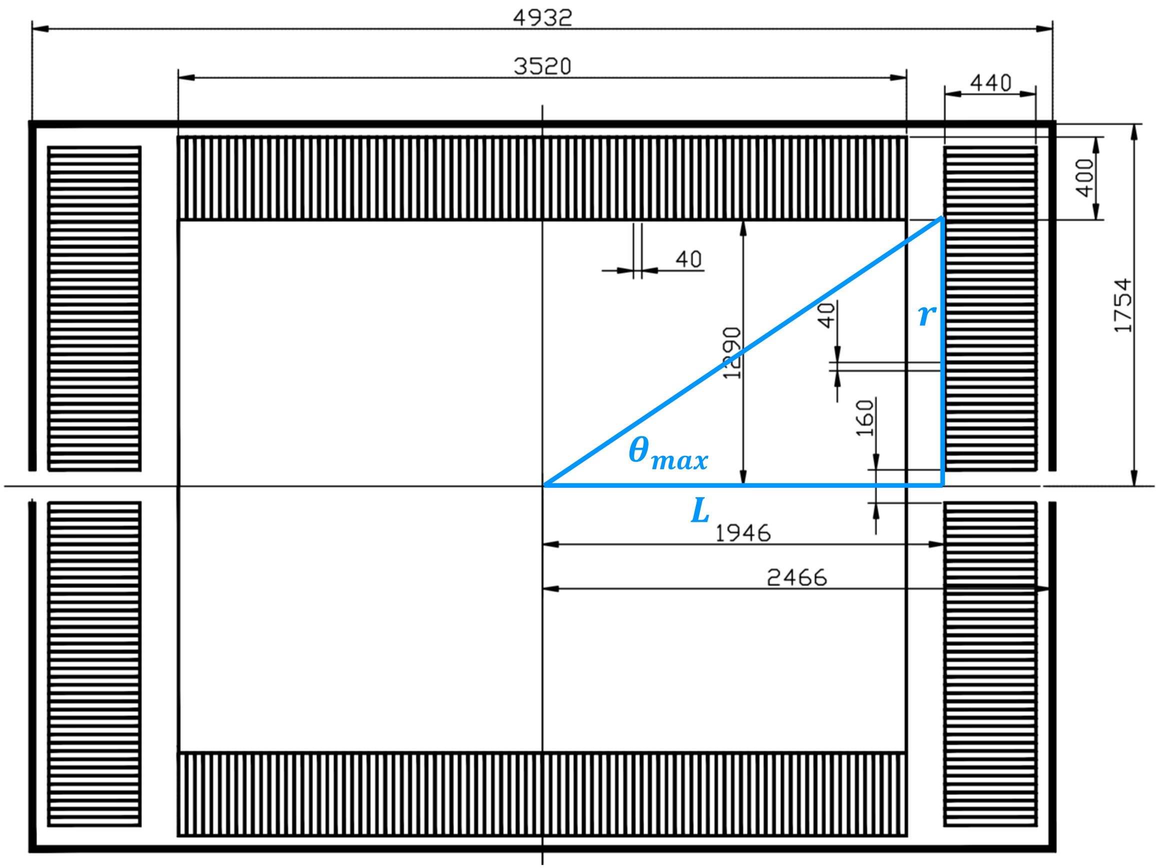
SPD local polarimetry with π^0 $(pp \rightarrow \pi^0 X)$



$$C = \tan\theta = \frac{r}{L}$$

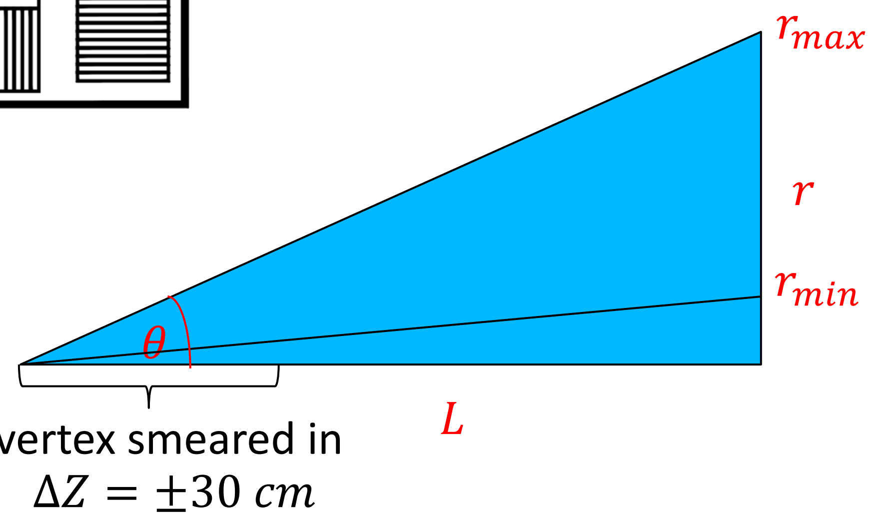
$$\Delta C = \frac{\Delta r}{L} = \frac{r_{max}}{L} - \frac{r_{min}}{L}$$

$$\Delta C = \frac{\Delta r}{L} = \frac{1354}{1946} - \frac{80}{1946} = 0.696 - 0.041$$

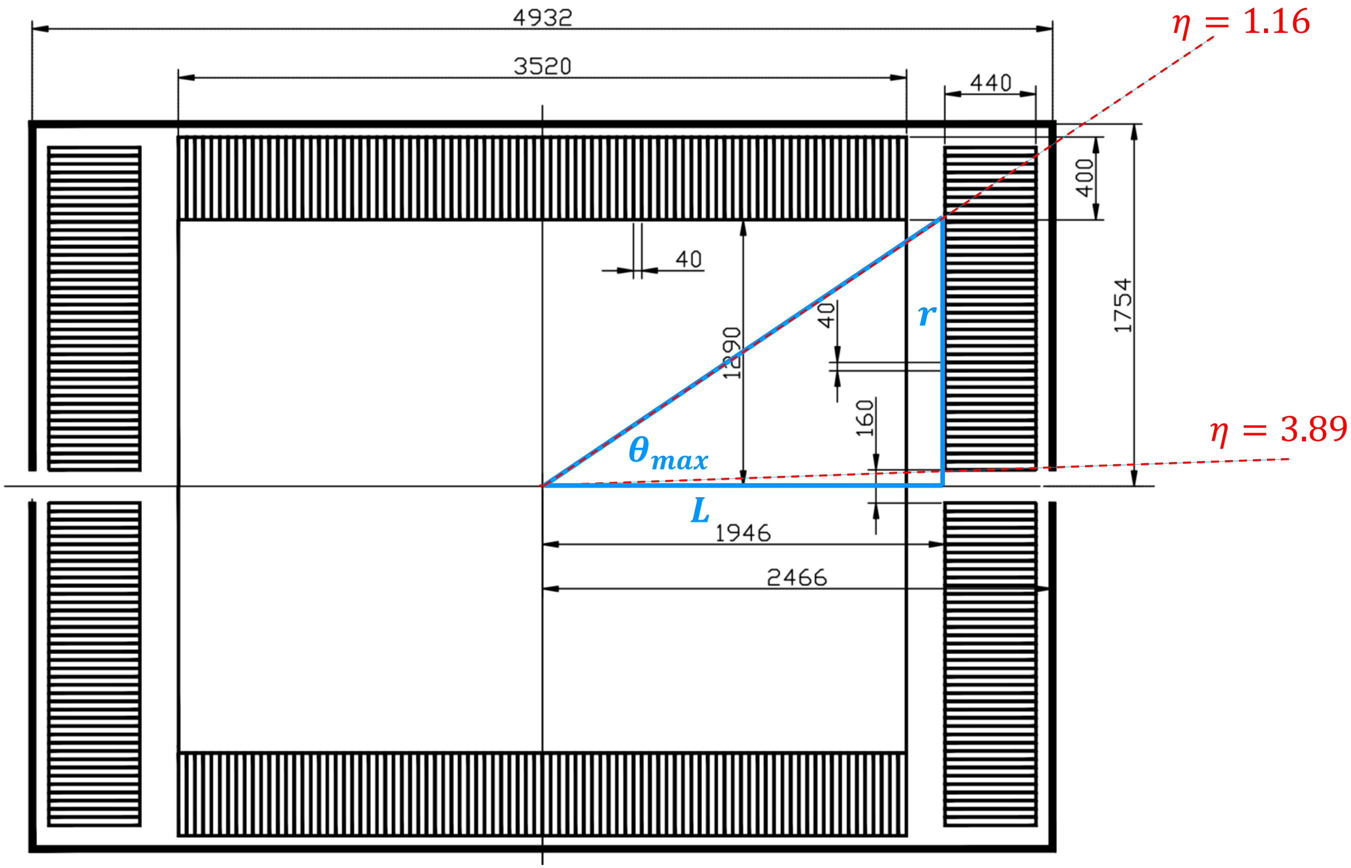
$$0.041 < \tan\theta < 0.696$$

$$\theta = \tan^{-1} C$$

$$\eta = -\ln\tan\frac{\theta}{2}$$



ECAL endcap coverage



$$C = \tan\theta = \frac{r}{L}$$

$$\Delta C = \frac{\Delta r}{L} = \frac{r_{max}}{L} - \frac{r_{min}}{L}$$

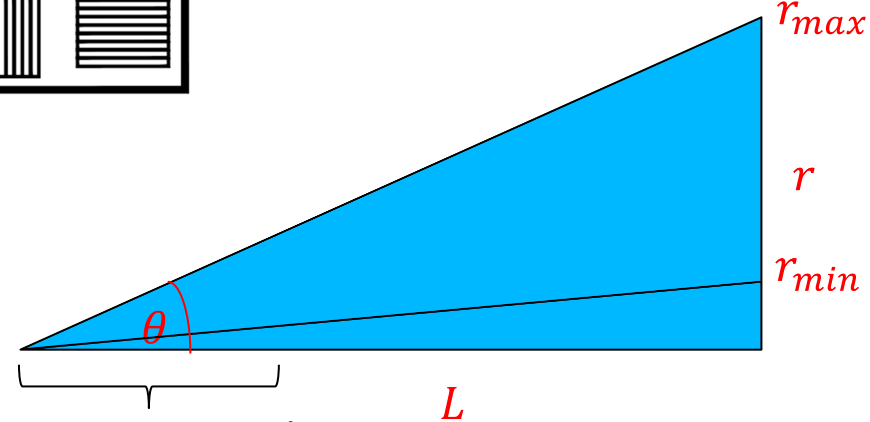
$$\Delta C = \frac{\Delta r}{L} = \frac{1354}{1946} - \frac{80}{1946} = 0.696 - 0.041$$

$$0.041 < \tan\theta < 0.696$$

$$\theta = \tan^{-1} C$$

$$\eta = -\ln\tan\frac{\theta}{2}$$

$2.3° < \theta < 34.8°$



vertex smeared in
$\Delta Z = \pm 30\ cm$

$$p + p \rightarrow \pi^0 + X$$
$$\pi^0 \rightarrow \gamma\gamma$$

Min. bias

SoftQCD:all	= on
PDF:pSet	= 15
BeamRemnants:primordialKT	= on
BeamRemnants:primordialKTsoft	= 1.1
BeamRemnants:primordialKThard	= 1.8
BeamRemnants:halfScaleForKT	= 2.0
BeamRemnants:halfMassForKT	= 4.0
BeamRemnants:reducedKTatHighY	= 0.7
BeamRemnants:primordialKTremnant	= 0.4
PhaseSpace:pTHatMinDiverge.	= 0.5

In Pythia this QCD process selection is intended to represent the total cross section of hadron collisions

$\boldsymbol{Pythia\ 8244}$

$\sqrt{s} = 27\ GeV$, 10^8 events

- Gaussian smearing on E_γ according to the ECal end-caps energy resolution:

$$\frac{\sigma_E}{E} = \frac{6.58\%}{\sqrt{E}} \oplus \frac{1.97\%}{E}$$

- Uniform distribution to smear the vertex in $\Delta Z = \pm 30\ cm$
- Cut low energy photons: $E_{min}^{\gamma} = 400\ MeV$

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

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

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

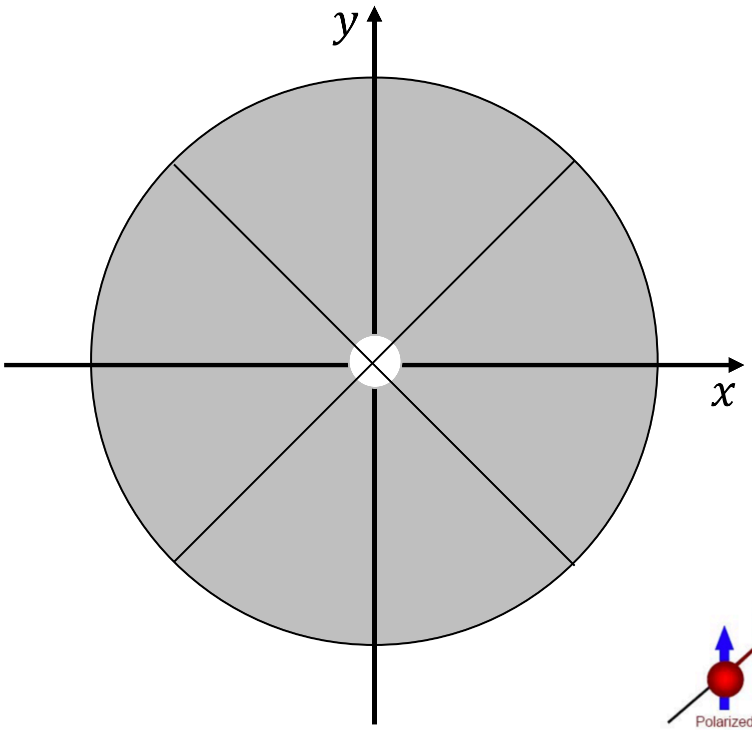
$$N_{\boldsymbol{\pi^0}}(\phi) = A(1 + B\cos\phi)$$

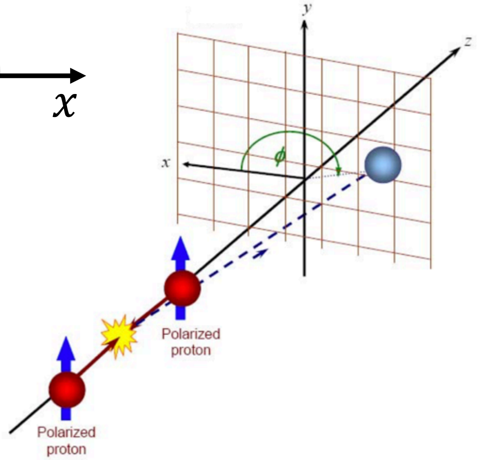
$$A_N = \frac{B}{P}$$

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

P: Beam polarization

- P ~ 0.7 was assumed

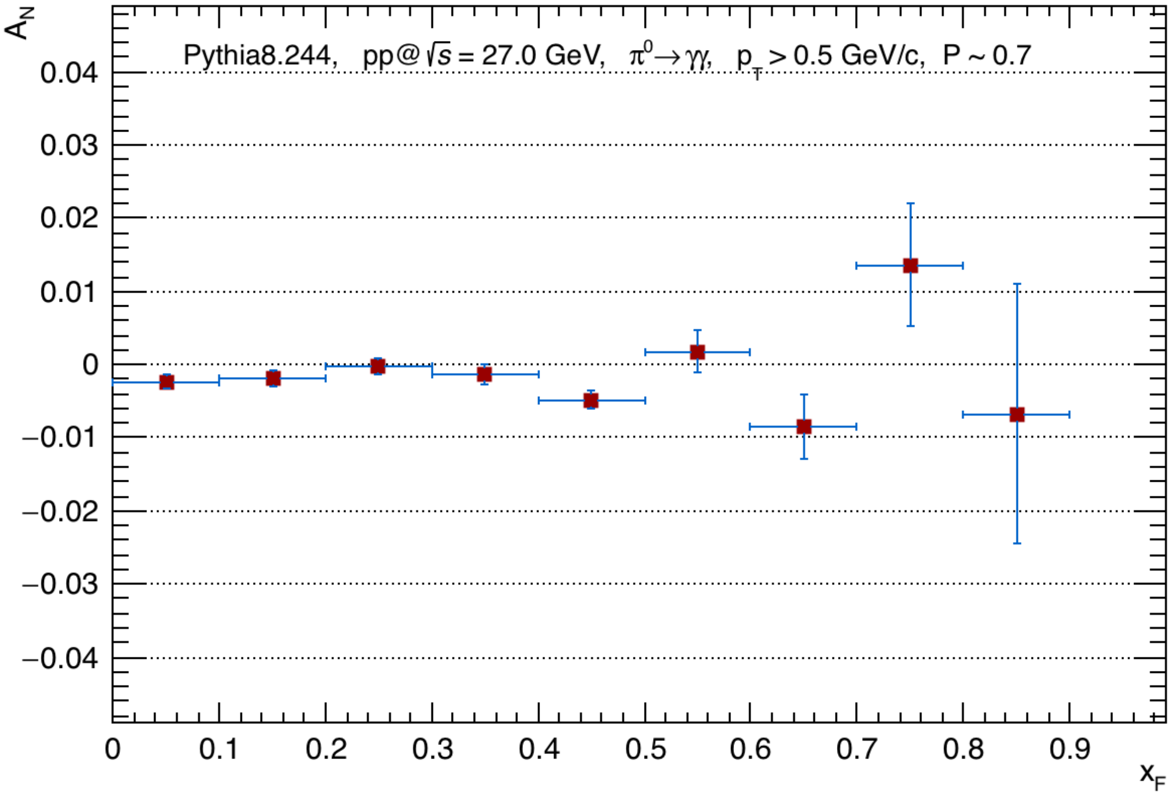




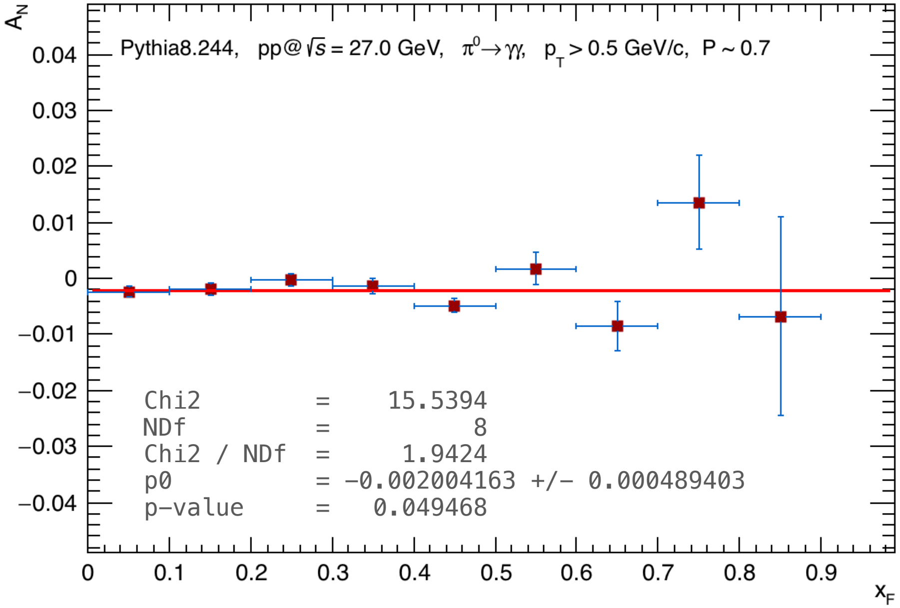
- 8 azimuthal bins.

- 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.

Transverse SSA (A_N)



$\langle x_F \rangle$	A_N	stat.
0.05	-0.0023	0.0009
0.15	-0.0018	0.0012
0.25	-0.0003	0.0011
0.35	-0.0013	0.0014
0.45	-0.0048	0.0012
0.55	-0.0017	0.0028
0.65	-0.0085	0.0043
0.75	0.0136	0.0083
0.85	-0.0067	0.0177



Assuming:

Collision rate: $4 \cdot 10^6 s^{-1}$

10^8 collisions is equivalent to 25 sec

Assuming 10 min of data taking the error should be less than 5%

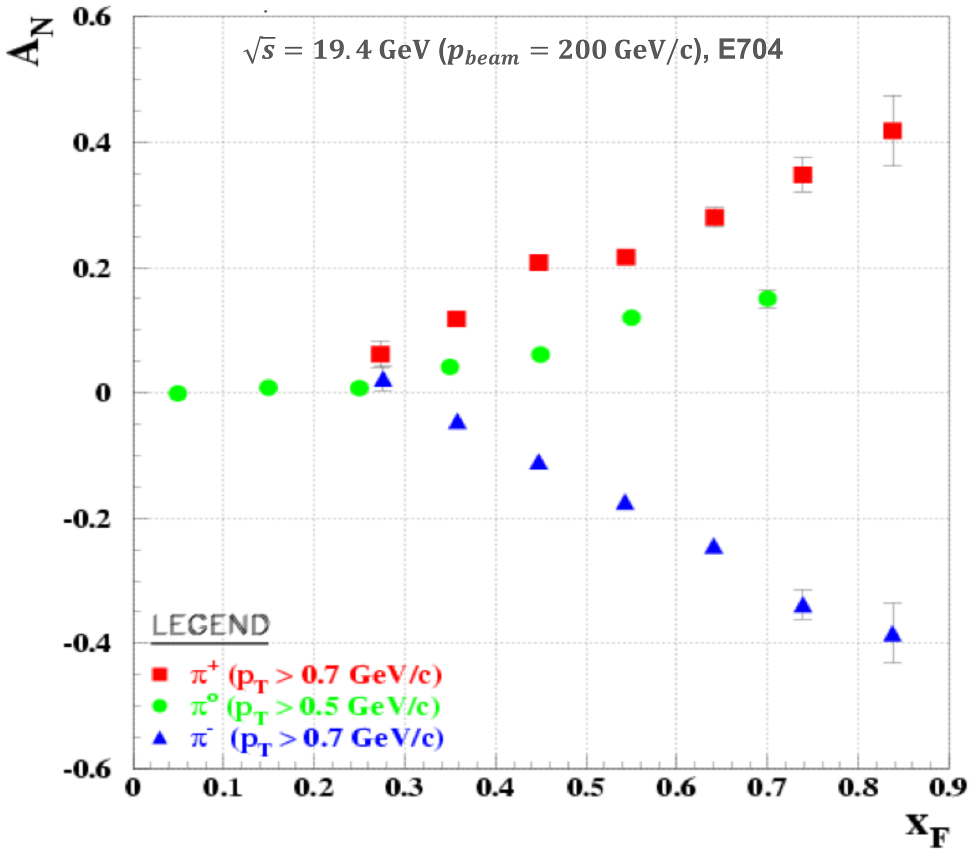
A_N for inclusive π^0 production in pp interactions

$$A_N = \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}}$$

In the early 70's was believed that SSA (A_N) was nearly vanishing in the framework of pQCD.

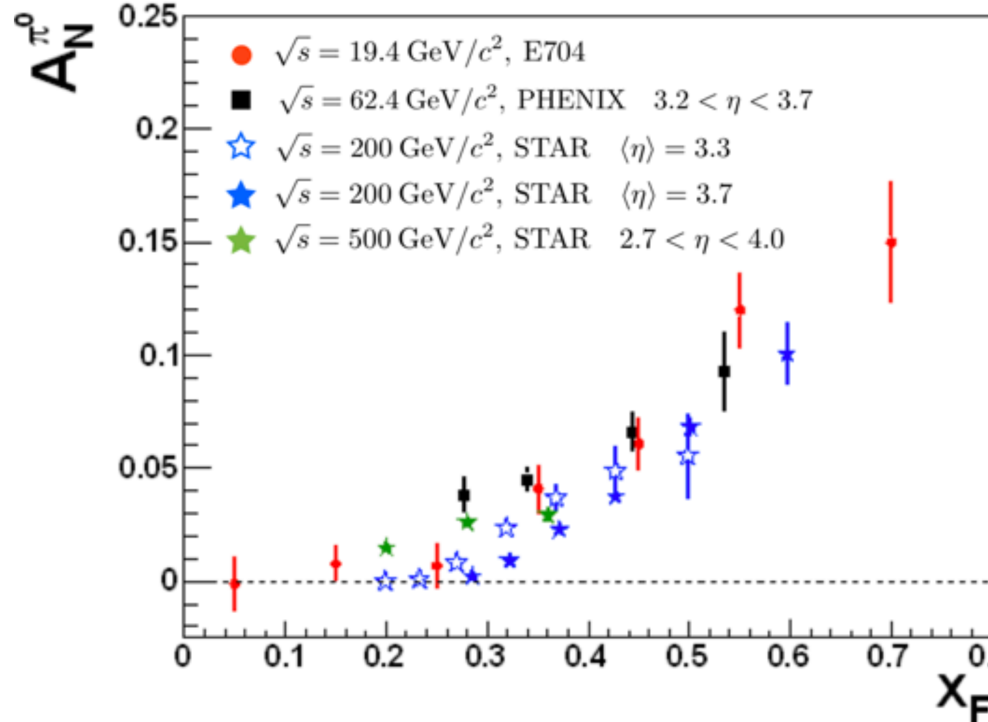
In 1991 the E704 experiment, with $\boldsymbol{p}^{\uparrow}$ at higher p_T values, extended the results on large A_N.

$$\boldsymbol{p}^{\uparrow} + \boldsymbol{p} \to \boldsymbol{\pi} + \boldsymbol{X}$$



E704: Adams et al. Phsy. Lett. B264(1991)462

A_N nearly independent of $\sqrt{s}$

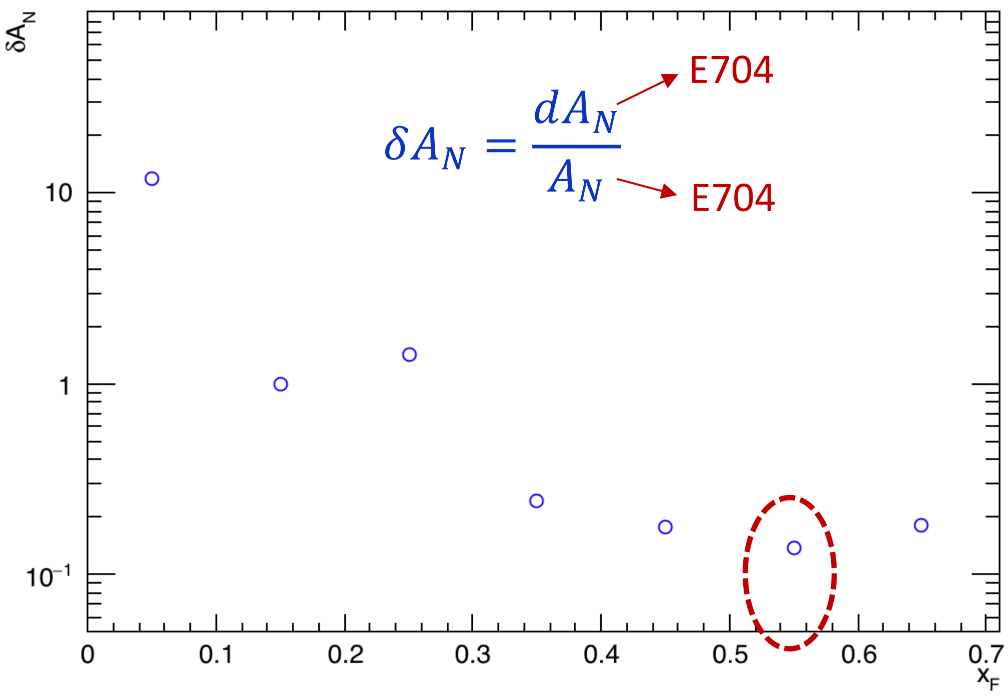


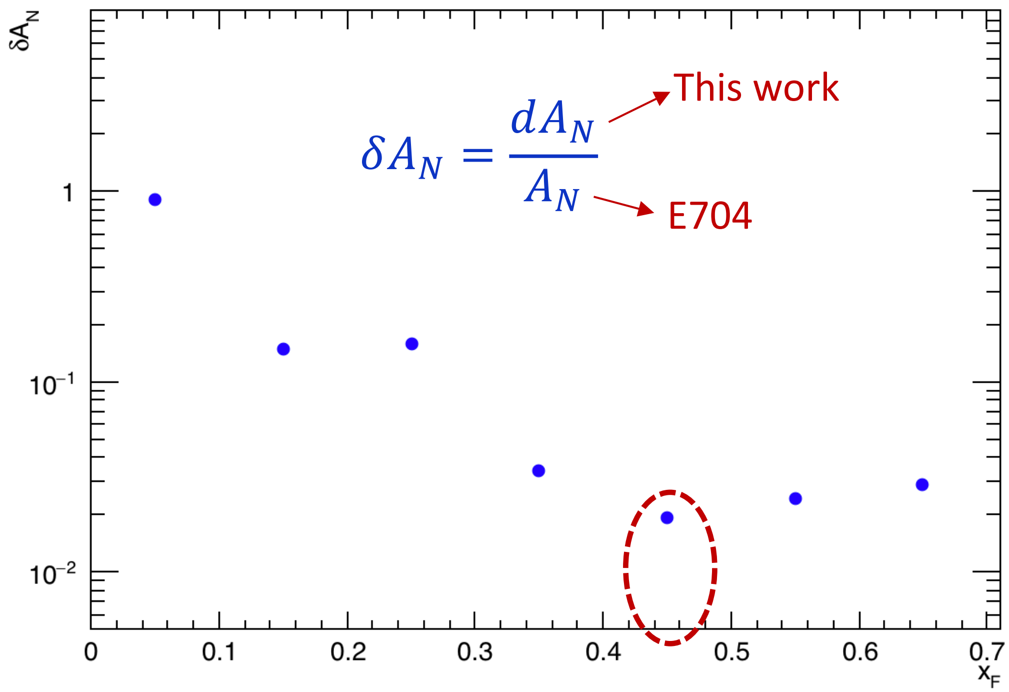
FERMILAB-Pub-91/15-E [E581, E704]

x_F	$\langle x_F \rangle$	p_T (GeV/c)	$\langle p_T \rangle$ (GeV/c)	No. π^0 Events	A_N $\bar{p}$ beam (%)	A_N p beam (%)
0.0 – 0.1	0.03	0.5 – 2.0	0.7	60 300	1.6 ± 1.4	−0.1 ± 1.2
0.1 – 0.2	0.13	0.5 – 2.0	0.7	151 600	0.4 ± 0.9	0.8 ± 0.8
0.2 – 0.3	0.23	0.5 – 2.0	0.7	117 100	2.9 ± 0.9	0.7 ± 1.0
0.3 – 0.4	0.33	0.6 – 2.0	0.8	87 800	3.1 ± 1.1	4.1 ± 1.0
0.4 – 0.5	0.43	0.7 – 2.0	0.9	44 600	5.0 ± 1.6	6.2 ± 1.1
0.5 – 0.6	0.53	0.8 – 2.0	0.9	19 600	6.8 ± 2.4	11.5 ± 1.6
0.6 – 0.8	0.67	0.8 – 2.0	1.0	7 300	7.2 ± 3.7	15.0 ± 2.7

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

$$\frac{dA_N}{A_N} \sim \frac{dP}{P}$$

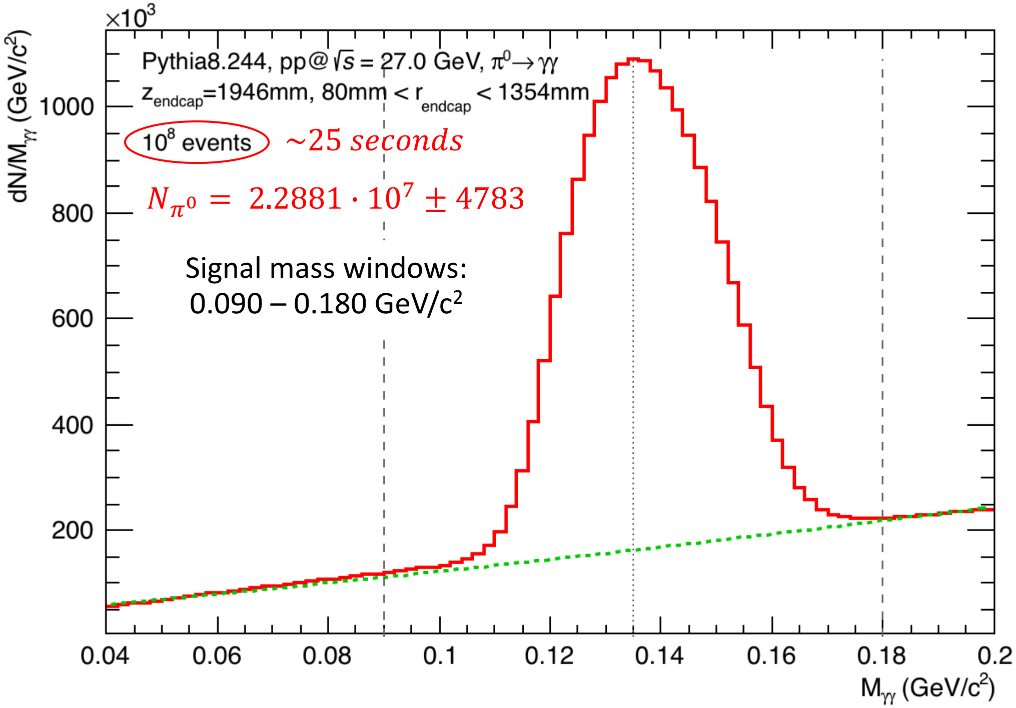


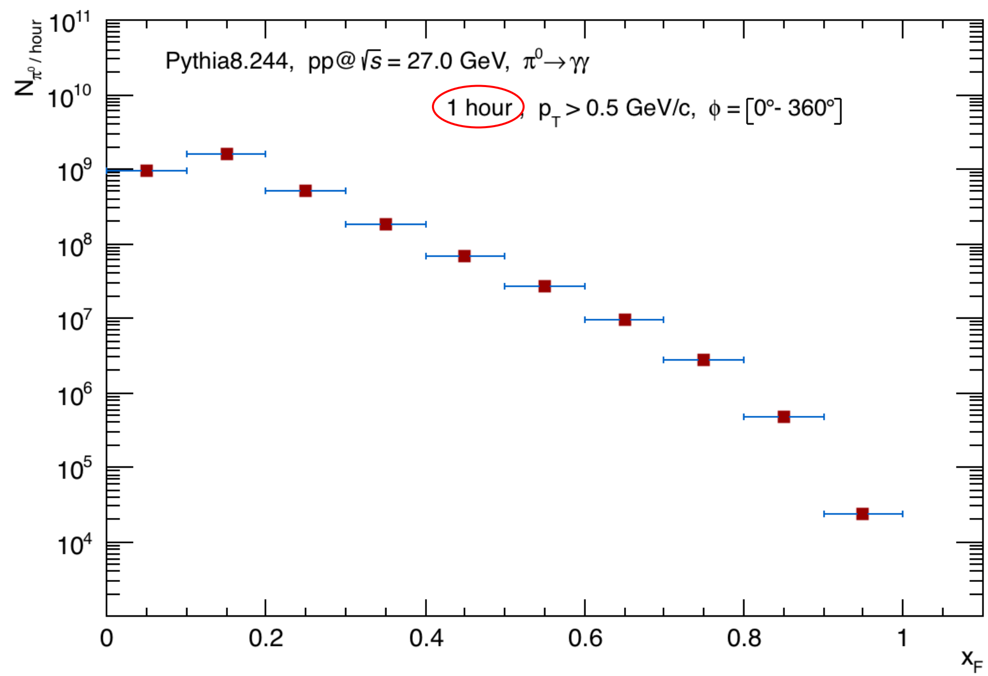


The determination of the polarization is expected to be precise for $0.4 < x_F < 0.6$.

All the azimuthal coverage

$$0° < \phi < 360°$$





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 $0° < \phi < 360°$

$$N_{\pi^0} = 3.29479 \cdot 10^9 \pm 57400$$

$0.0 \leq x_F < 0.1$: $9.39654e{+}08 \pm 30653.8$

$0.1 \leq x_F < 0.2$: $1.56526e{+}09 \pm 39563.4$

$0.2 \leq x_F < 0.3$: $5.04026e{+}08 \pm 22450.5$

$0.3 \leq x_F < 0.4$: $1.77998e{+}08 \pm 13341.6$

$0.4 \leq x_F < 0.5$: $6.84376e{+}07 \pm 8272.7$

$0.5 \leq x_F < 0.6$: $2.66409e{+}07 \pm 5161.49$

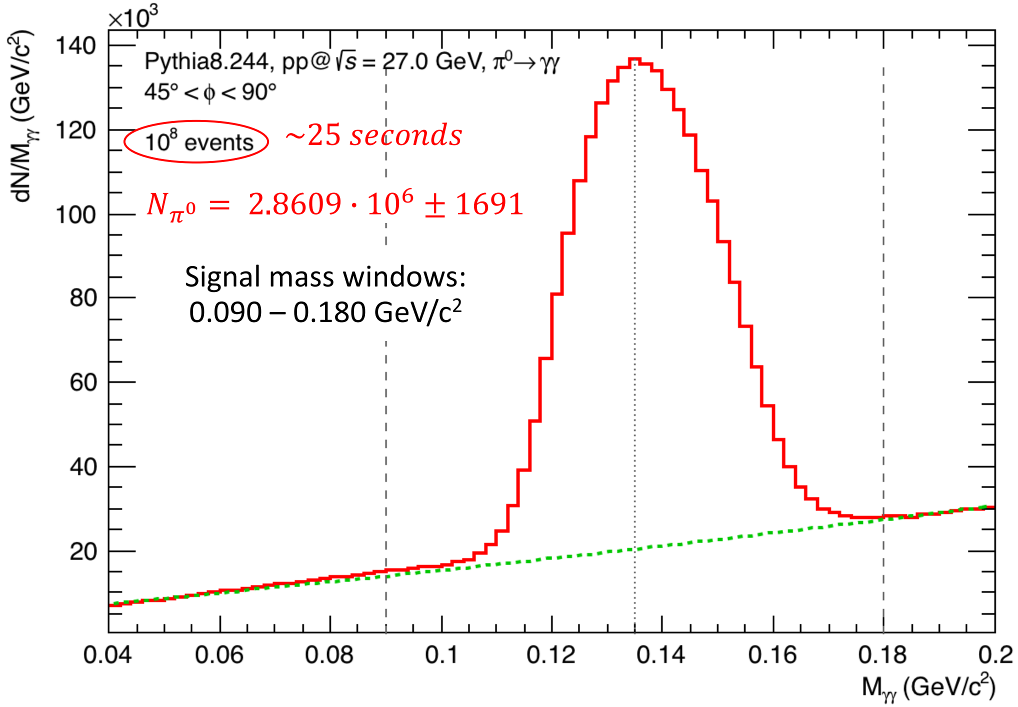
$0.6 \leq x_F < 0.7$: $2.66409e{+}07 \pm 5161.49$

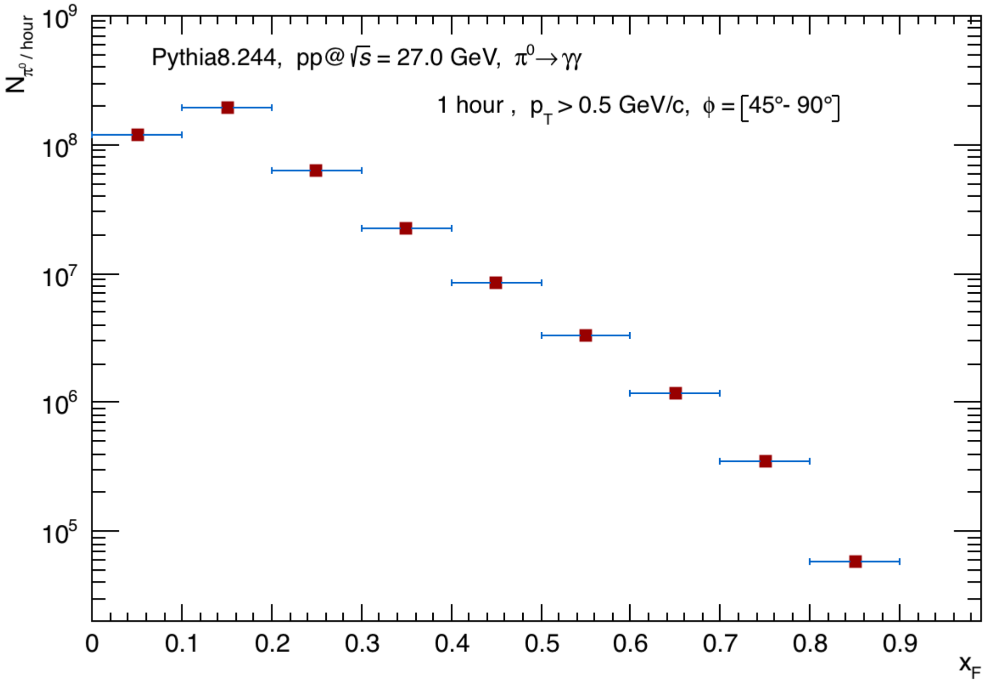
$0.7 \leq x_F < 0.8$: $2.77713e{+}06 \pm 1666.47$

$0.8 \leq x_F < 0.9$: 473567 ± 688.162

One ϕ bin

$45° < \phi < 90°$





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 ($\pi^0 \rightarrow \gamma\gamma$) in one ϕ bin: $45° < \phi < 90°$

$$N_{\pi^0} = 4.1198 \cdot 10^8 \pm 20297$$

$0.0 \leq x_F < 0.1$: 1.17536e+08 $\pm$ 10841.4
$0.1 \leq x_F < 0.2$: 1.95761e+08 $\pm$ 13991.5
$0.2 \leq x_F < 0.3$: 6.29991e+07 $\pm$ 7937.21
$0.3 \leq x_F < 0.4$: 2.22078e+07 $\pm$ 4712.51
$0.4 \leq x_F < 0.5$: 8.55007e+06 $\pm$ 2924.05
$0.5 \leq x_F < 0.6$: 3.32296e+06 $\pm$ 1822. 9
$0.6 \leq x_F < 0.7$: 3.32296e+06 $\pm$ 1822. 9
$0.7 \leq x_F < 0.8$: 346309 $\pm$ 588.48
$0.8 \leq x_F < 0.9$: 57600 $\pm$ 240

π^0 yields

```
1. ---> Inv. mass, deg [-180,-135] <phi> = -157.5 deg (-2.74889 rad) , (pt_pi0 > 0.5), 10^8 events
0.0<=xf<0.1 : 818436 +- 904.674
0.1<=xf<0.2 : 1.36344e+06 +- 1167.67
0.2<=xf<0.3 : 436759 +- 660.878
0.3<=xf<0.4 : 154598 +- 393.19
0.4<=xf<0.5 : 59526.9 +- 243.981
0.5<=xf<0.6 : 22942.4 +- 151.468
0.6<=xf<0.7 : 22942.4 +- 151.468
0.7<=xf<0.8 : 2327.85 +- 48.2478
0.8<=xf<0.9 : 389 +- 19.7231

2. ---> Inv. mass, deg [-135,-90] <phi> = -112.5 deg (-1.9635 rad) , (pt_pi0 > 0.5), 10^8 events
0.0<=xf<0.1 : 817287 +- 904.039
0.1<=xf<0.2 : 1.36247e+06 +- 1167.25
0.2<=xf<0.3 : 439615 +- 663.035
0.3<=xf<0.4 : 155251 +- 394.02
0.4<=xf<0.5 : 59620 +- 244.172
0.5<=xf<0.6 : 23243.3 +- 152.458
0.6<=xf<0.7 : 23243.3 +- 152.458
0.7<=xf<0.8 : 2402.89 +- 49.0193
0.8<=xf<0.9 : 419 +- 20.4695

3. ---> Inv. mass, deg [-90,-45] <phi> = -67.5 deg (-1.1781 rad) , (pt_pi0 > 0.5), 10^8 events
0.0<=xf<0.1 : 815772 +- 903.201
0.1<=xf<0.2 : 1.35543e+06 +- 1164.23
0.2<=xf<0.3 : 437655 +- 661.555
0.3<=xf<0.4 : 154333 +- 392.853
0.4<=xf<0.5 : 59231 +- 243.374
0.5<=xf<0.6 : 23098.3 +- 151.981
0.6<=xf<0.7 : 23098.3 +- 151.981
0.7<=xf<0.8 : 2412.9 +- 49.1213
0.8<=xf<0.9 : 410 +- 20.2485

4. ---> Inv. mass, deg [-45,0] <phi> = -22.5 deg (-0.392699 rad) , (pt_pi0 > 0.5), 10^8 events
0.0<=xf<0.1 : 814496 +- 902.494
0.1<=xf<0.2 : 1.35436e+06 +- 1163.77
0.2<=xf<0.3 : 436967 +- 661.035
0.3<=xf<0.4 : 154253 +- 392.751
0.4<=xf<0.5 : 59090.5 +- 243.085
0.5<=xf<0.6 : 23183.4 +- 152.261
0.6<=xf<0.7 : 23183.4 +- 152.261
0.7<=xf<0.8 : 2450.84 +- 49.506
0.8<=xf<0.9 : 414 +- 20.347
```

π^0 yields

```
5. ---> Inv. mass, deg [0,45] <phi> = 22.5 deg (0.392699 rad) , (pt_pi0 > 0.5), 10^8 events
0.0<=xf<0.1 : 813706 +- 902.057
0.1<=xf<0.2 : 1.36038e+06 +- 1166.35
0.2<=xf<0.3 : 437173 +- 661.19
0.3<=xf<0.4 : 154449 +- 393
0.4<=xf<0.5 : 59405.8 +- 243.733
0.5<=xf<0.6 : 22979.1 +- 151.589
0.6<=xf<0.7 : 22979.1 +- 151.589
0.7<=xf<0.8 : 2429.92 +- 49.2942
0.8<=xf<0.9 : 404 +- 20.0998

6. ---> Inv. mass, deg [45,90] <phi> = 67.5 deg (1.1781 rad) , (pt_pi0 > 0.5), 10^8 events
0.0<=xf<0.1 : 816224 +- 903.451
0.1<=xf<0.2 : 1.35945e+06 +- 1165.95
0.2<=xf<0.3 : 437495 +- 661.434
0.3<=xf<0.4 : 154221 +- 392.709
0.4<=xf<0.5 : 59375.5 +- 243.671
0.5<=xf<0.6 : 23076.1 +- 151.908
0.6<=xf<0.7 : 23076.1 +- 151.908
0.7<=xf<0.8 : 2404.92 +- 49.04
0.8<=xf<0.9 : 400 +- 20

7. ---> Inv. mass, deg [90,135] <phi> = 112.5 deg (1.9635 rad) , (pt_pi0 > 0.5), 10^8 events
0.0<=xf<0.1 : 814816 +- 902.671
0.1<=xf<0.2 : 1.35728e+06 +- 1165.02
0.2<=xf<0.3 : 437548 +- 661.474
0.3<=xf<0.4 : 154943 +- 393.628
0.4<=xf<0.5 : 59318.5 +- 243.554
0.5<=xf<0.6 : 23291.2 +- 152.614
0.6<=xf<0.7 : 23291.2 +- 152.614
0.7<=xf<0.8 : 2394.87 +- 48.9374
0.8<=xf<0.9 : 433 +- 20.8087

8. ---> Inv. mass, deg [135,180] <phi> = 157.5 deg (2.74889 rad) , (pt_pi0 > 0.5), 10^8 events
0.0<=xf<0.1 : 814637 +- 902.572
0.1<=xf<0.2 : 1.35707e+06 +- 1164.93
0.2<=xf<0.3 : 436973 +- 661.039
0.3<=xf<0.4 : 154048 +- 392.489
0.4<=xf<0.5 : 59693.2 +- 244.322
0.5<=xf<0.6 : 23193.2 +- 152.293
0.6<=xf<0.7 : 23193.2 +- 152.293
0.7<=xf<0.8 : 2461.94 +- 49.6179
0.8<=xf<0.9 : 420 +- 20.4939
```

The $p^{\uparrow} + p \rightarrow \boldsymbol{\pi^0} + X$ inclusive reaction seems to be suitable for local polarimetry in SPD

The A_N of $\boldsymbol{\pi^0}$ for polarimetry purposes can be performed with large enough statistics, although this should be better evaluated after defining additional cuts. i.e. ECAL-Encaps granularity.

Better precision of polarization measurements is expected in $0.4 < x_F < 0.6$.