

Upper limit on beam polarization for  
single spin asymmetry collisions

# Polarization Profiles

- Polarization loss from intrinsic resonances: polarization lost at edge of beam → polarization profile.
- Impact of polarization profile on beam polarization at collisions:

$$P(x, x', y, y') = P_0 e^{-\frac{x^2+x'^2}{2\sigma_{x,P}^2}} e^{-\frac{y^2+y'^2}{2\sigma_{y,P}^2}} ; I(x, x', y, y') = I_0 e^{-\frac{x^2+x'^2}{2\sigma_{x,I}^2}} e^{-\frac{y^2+y'^2}{2\sigma_{y,I}^2}} ; R_H = \frac{\sigma_{x,I}^2}{\sigma_{x,P}^2} ; R_V = \frac{\sigma_{y,I}^2}{\sigma_{y,P}^2}$$

$$P_{jet} = \frac{P_0}{(1 + R_H)(1 + R_V)}$$

$$P_{coll} = P_{jet} \sqrt{\frac{(1 + R_V)(1 + R_H)}{(1 + \frac{1}{2} R_V)(1 + \frac{1}{2} R_H)}}$$

$\langle P \rangle = P_{jet}$ -average polarization measured by H-jet or p-Carbon polarimeter in a sweep mode.  $P_0$ -maximum polarization in the beam center.

For  $R_H \approx R_V = R$  and small:  $P_0 = P_{jet} (1+R)^2$  ;

$P_{coll.} = P_{jet} (1 + \frac{1}{2}R)$

# AGS to RHIC polarization Transfer:

$$P_{fix}^V = \frac{P_0}{(1 + R_V)\sqrt{1 + R_H}}$$

$$\langle P \rangle = \frac{P_{fix}^V}{\sqrt{1 + R_H}} \sim P_{fix}^V \left(1 - \frac{1}{2} R_H\right) \quad \langle P \rangle = \frac{P_{fix}^V}{\sqrt{1 + R_H}} = \frac{P_0}{(1 + R_H)(1 + R_V)}$$

$$\langle P \rangle \sim 71 \times (1 - \frac{1}{2} 0.08) \sim 68 \%$$

AGS to RHIC Transfer:

Blue:  $\langle P \rangle \times 0.96 \sim 65.4\%$ ,  $P_0 = 76.8 \%$

Yellow:  $\langle P \rangle \times 0.99 \sim 67.5\%$ ,  $P_0 = 79\%$

# Run-12, $P_0$ -maximum polarization, $P_{coll}$ - polarization for colliding beams.

	24 GeV		100 GeV		255 GeV	
	B	Y	B	Y	B	Y
$\langle P \rangle$ Hjet		$63 \pm 3.5$	61.1	57.0	51.7	53.7
R	0.05	0.06	0.10	0.16	0.17	0.15
$P_0$		71 %	72%	76 %	71 %	71 %
$P_{coll}$			64%	61%	56%	58 %

About 3-5% errors, mostly systematic on all above numbers.

Blue- X 0.96=69%

Yellow- X 0.99=71%

Run 13,  $P_0$  -maximum polarization,  $P_{\text{coll}}$ -polarization  
for colliding beams.

	24 GeV			255 GeV	
	B	Y		B	Y
$\langle P \rangle$	65%, AGS	68%, AGS		44.0	52.9
R	0.08	0.08		0.27	0.18
$P_0$	76%	79%		71%	74%
$P_{\text{coll}}$				50%	58 %

About +/-3-5% errors, mostly systematic on all above numbers.

Run 13,  $P_0$  -maximum polarization,  $P_{coll}$ -polarization  
for colliding beams. Fills-17396-17440

	24 GeV			255 GeV	
	B	Y		B	Y
$\langle P \rangle$	65%, AGS	66%, AGS		53.5	57.9
R	0.08	0.08			0.11
$P_0$	76%	79%			71.3%
$P_{coll}$					61 %

About +/-3-5% errors, mostly systematic on all above numbers.

Polarization profile R might be underestimated due to rate effects (AGS) and target deformation (largest effects at 255 GeV).

- Therefore  $P_0$  value can be larger.
- Ideally for Yellow  $P_0$  should be the Source Polarization:  $80 \times 0.99 = 79\%$

$$\langle P \rangle = \frac{P_0}{(1 + R_H)(1 + R_V)}$$

For  $R_H \approx R_V = R$ ,  $P_0 = 0.80$ ,  $\langle P \rangle = P_{\text{jet}} = 60\%$   
 $R \sim 0.15$  - upper limit on R.

$$P_{\text{coll}} \sim \langle P \rangle \left(1 + \frac{R_V + R_H}{4}\right) \longrightarrow P_{\text{coll}} \sim 64.5\% \text{-upper limit}$$

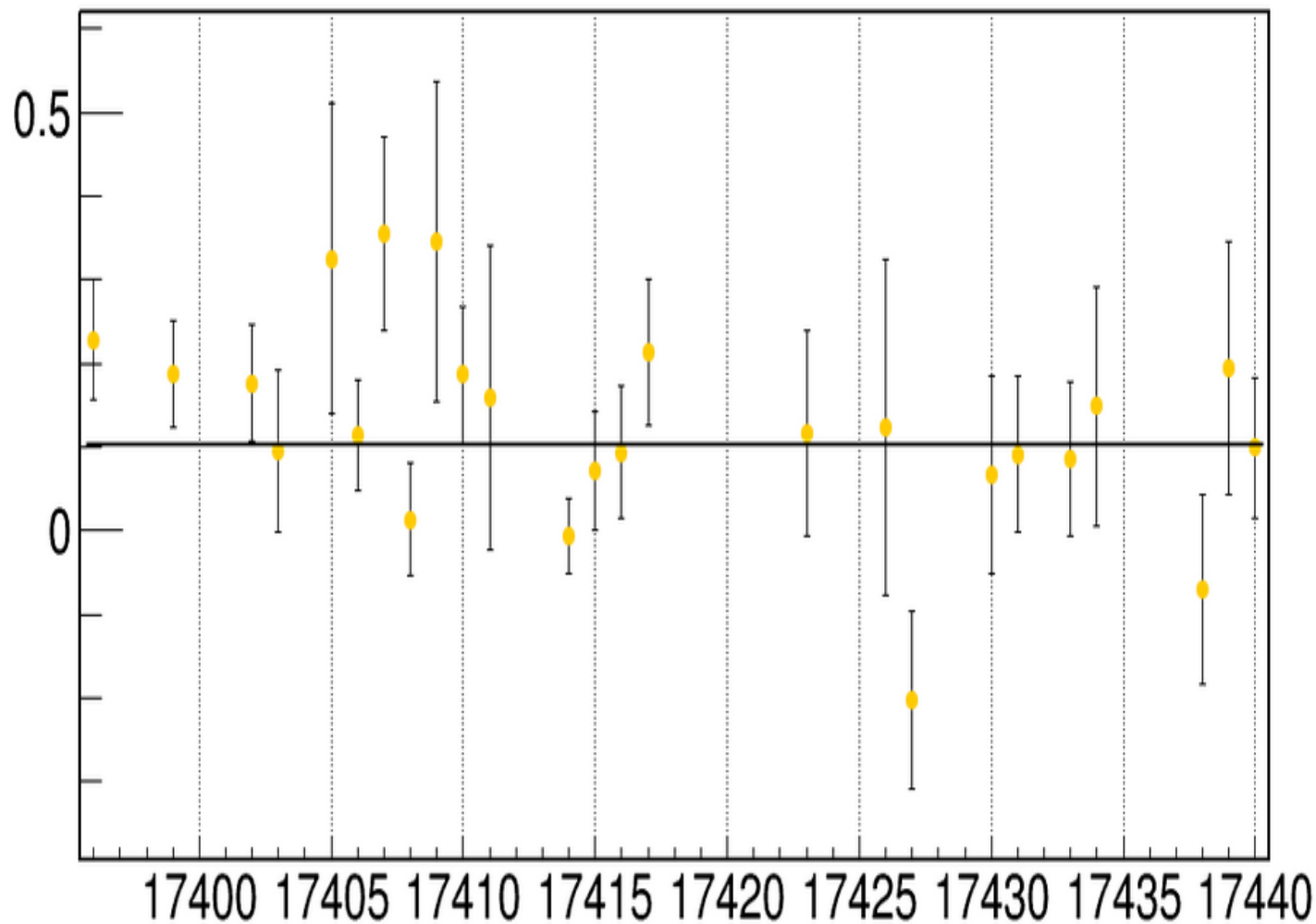
For  $R=0.1 \rightarrow P_{\text{pC}} \sim 63\%$

$$P_{\text{pC}} \sim 63\% < P_{\text{coll}} < 64.5\%$$

•Of course, there are systematic errors in H-jet numbers too.

# R, Yellow-2

Fills 17396--17440, Analyzed Tue Apr 30 17:25:01 2013, Version 2045, dsmirnov

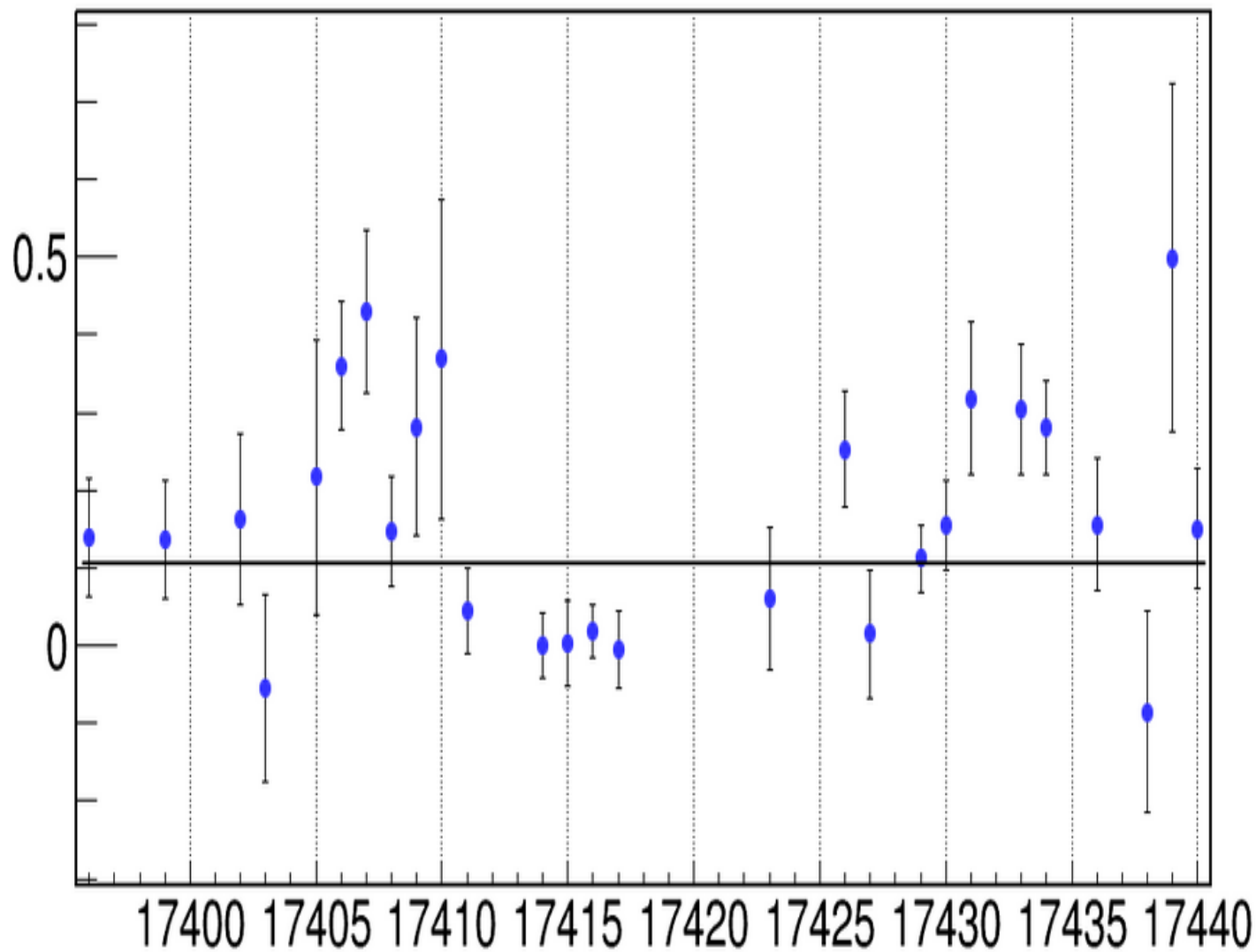


$\chi^2 / \text{ndf}$	35.78 / 24
Prob	0.05764
p0	$0.1033 \pm 0.01741$



# R, Blue-2

Fills 17396--17440, Analyzed Tue Apr 30 17:25:01 2013, Version 2045, dsmirnov



$\chi^2 / \text{ndf}$	78.82 / 26
Prob	3.183e-07
p0	0.1053 ± 0.01318

# Polarization (single spin asymmetry) in collisions P<sub>coll</sub> vs. P<sub>jet</sub>

$$P_{jet} = \frac{P_0}{(1 + R_H)(1 + R_V)}$$

$$\text{For } -R_V = R_H = R \Rightarrow 1 + R = \sqrt{\frac{P_0}{P_{jet}}}$$

$$P_{coll} = P_{jet} \sqrt{\frac{(1 + R_V)(1 + R_H)}{(1 + \frac{1}{2}R_V)(1 + \frac{1}{2}R_H)}} = P_{jet} \frac{1 + R}{1 + \frac{1}{2}R} = \frac{2P_{jet}}{1 + \frac{1}{1 + R}} = \frac{2P_{jet}}{1 + \sqrt{\frac{P_{jet}}{P_0}}}$$

Maximum  $P_0 \sim 80\%$ -source polarization  
(81% X 0.99  $\sim 80\%$ -for Yellow, 81% X 0.96  $\sim 78\%$  for Blue).

For  $R \ll 1$  corrections for double spin asymmetry are small  $\sim (R_V^2 + R_H^2)/8$ .

# Upper limit for polarization in collisions (single spin asymmetry) vs. H-jet polarization.

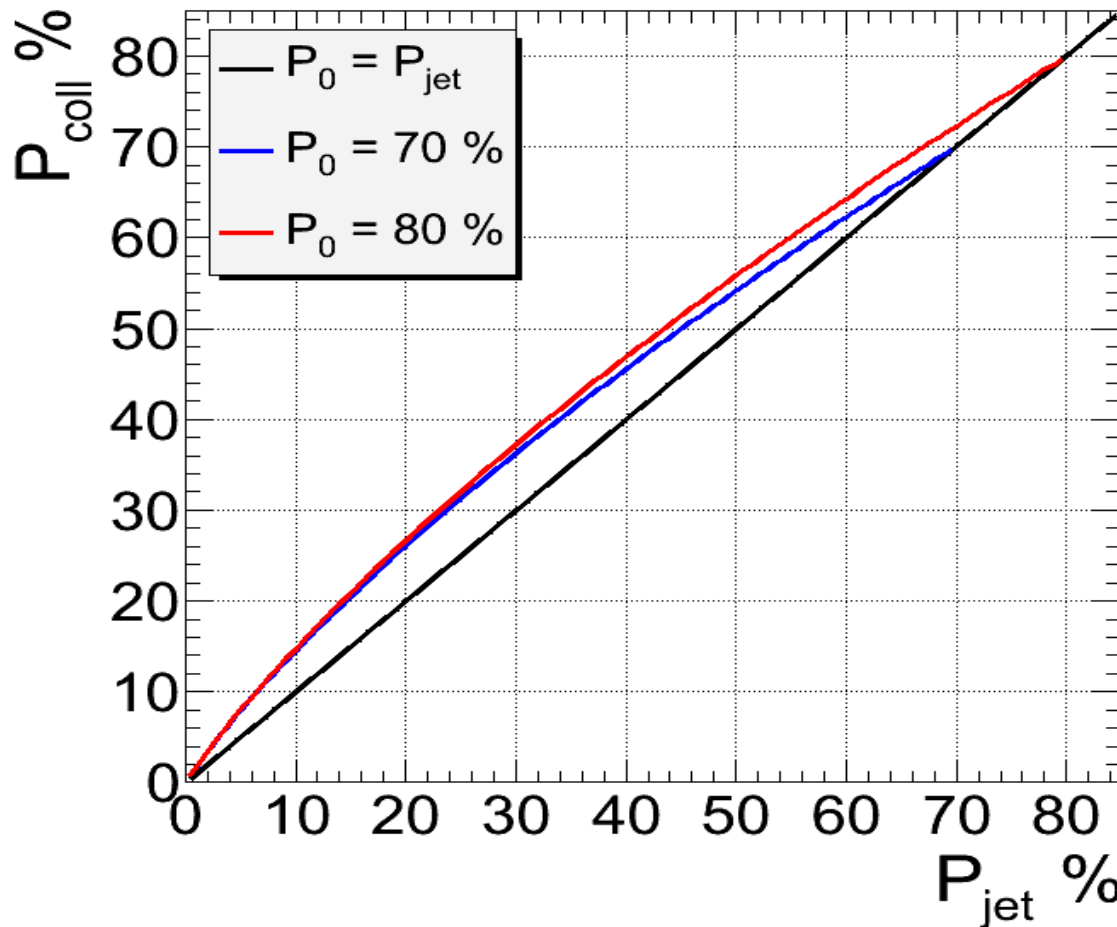
$$P_{coll} = \frac{2P_{jet}}{1 + \sqrt{\frac{P_{jet}}{P_0}}}$$

$P_0=80\%$  - Red line

$P_0=70\%$  - Blue line

$P_{jet}$  - black line  
low limit on  $P_{coll}$

For  $P_0=60\%$ , maximum  
 $P_{coll} \sim 64.5\%$



$R=0.1$ ,  $P_{coll,pC} \sim 62.9\%$

$60\% < P_{pC} = 62.9\% \leq P_{exp} < 64.5\%$

### 3 Corrections

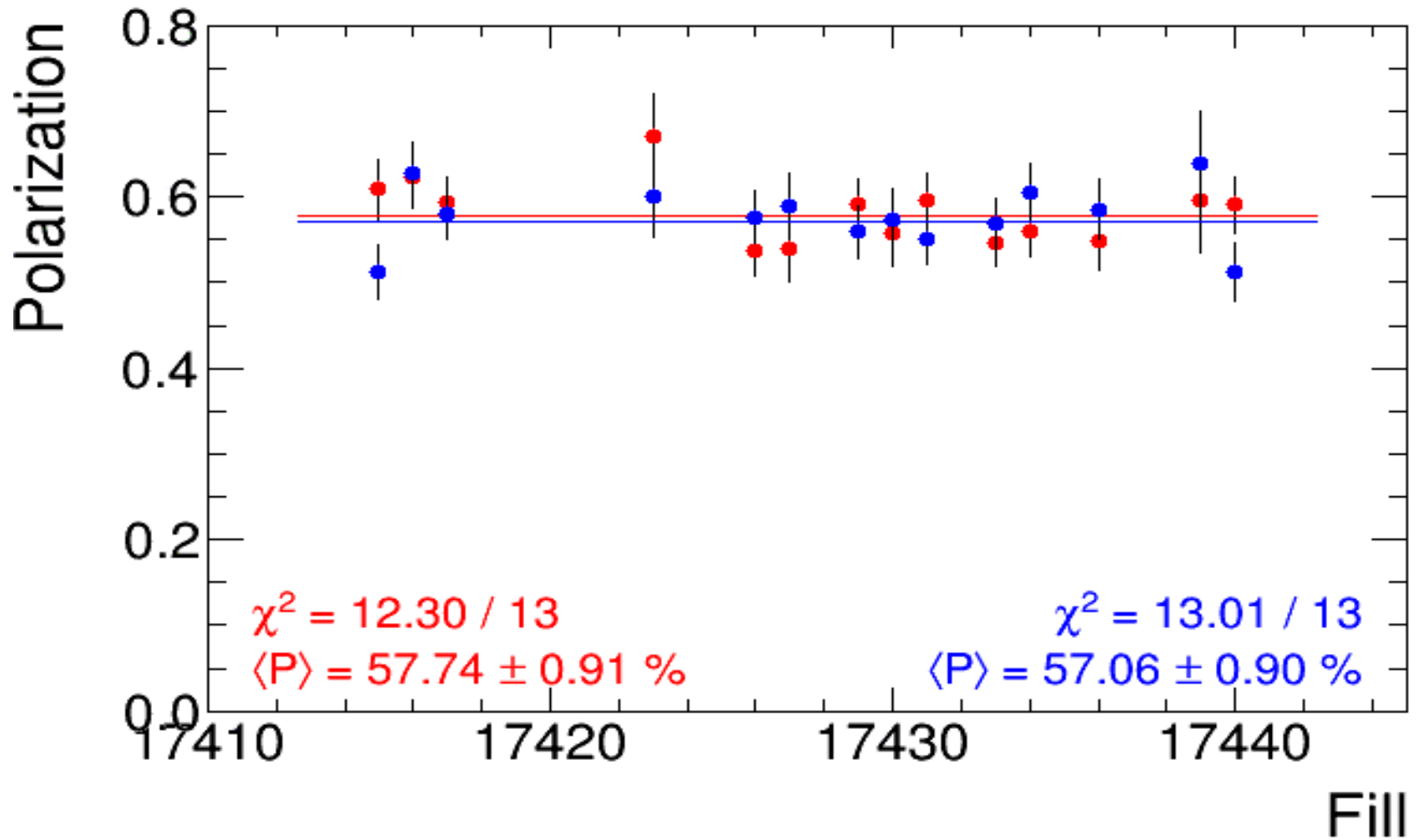
As can be derived from the comparison of Eq. (10) and (1), for the simplified case defined above, the polarization measured by a polarimeter  $\bar{P}$  is smaller than polarization observed in a collision  $\langle P \rangle$ , hence, in order to be used in a collision experiment measurements,  $\bar{P}$  should be corrected by a factor of

$$\frac{\langle P \rangle}{\bar{P}} = \sqrt{\frac{(1 + R_x)(1 + R_y)}{(1 + \frac{1}{2}R_x)(1 + \frac{1}{2}R_y)}} \approx 1 + \frac{1}{4}(R_x + R_y) \text{ for } R_x, R_y \ll 1. \quad (11)$$

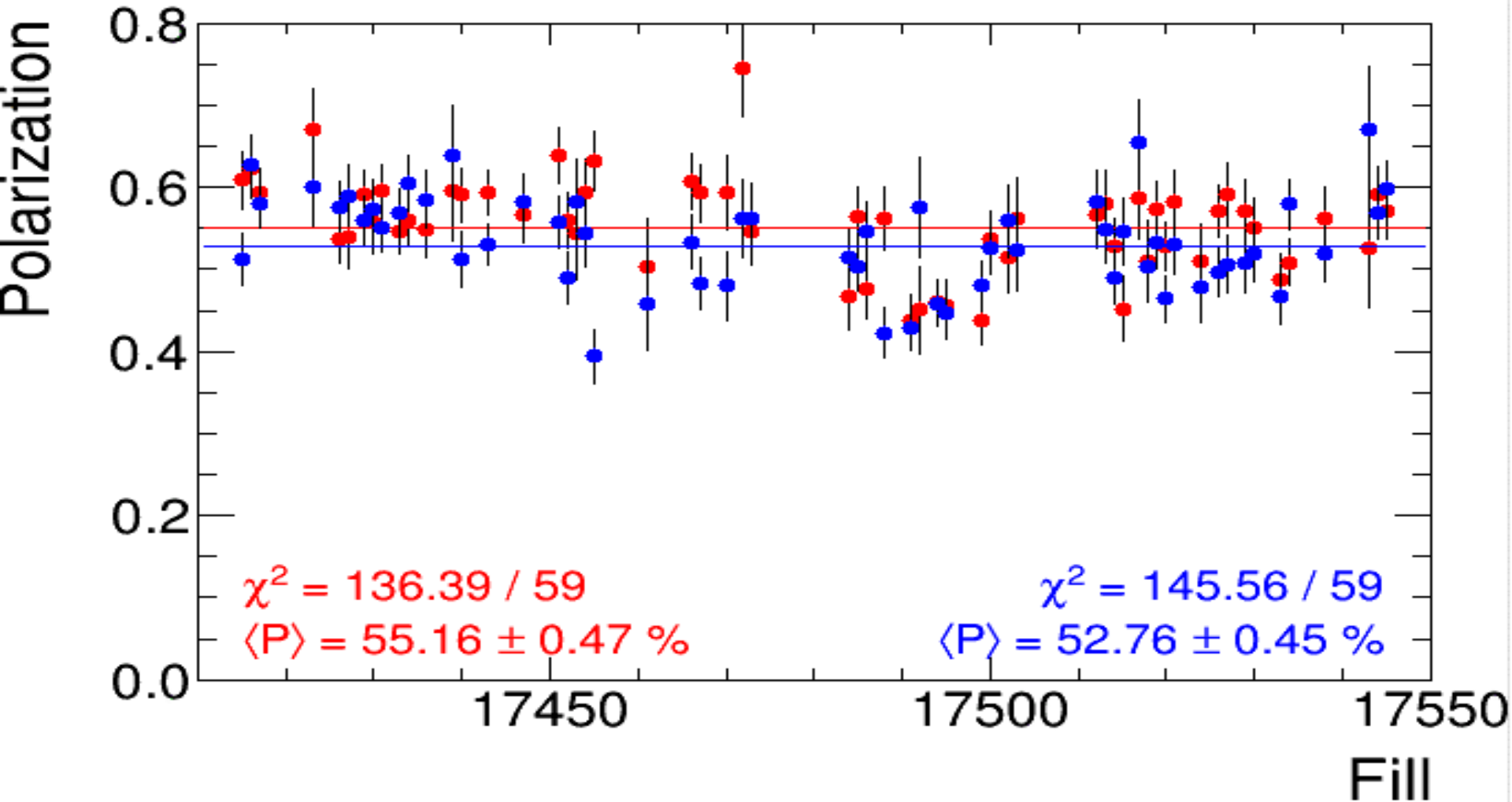
When measuring double spin asymmetries, the measured asymmetries are normalized by  $\langle \vec{P}_B \cdot \vec{P}_Y \rangle$ , for which  $M_{11}$  value should be provided. It can be derived from  $\langle P_B \rangle \cdot \langle P_Y \rangle$  by correcting it by a factor of

$$\frac{\langle P_B \cdot P_Y \rangle}{\langle P_B \rangle \cdot \langle P_Y \rangle} = \frac{(1 + \frac{1}{2}R_x)(1 + \frac{1}{2}R_y)}{[(1 + R_x)(1 + R_y)]^{1/2}} \approx 1 + \frac{1}{8}(R_x^2 + R_y^2) \text{ for } R_x, R_y \ll 1. \quad (12)$$

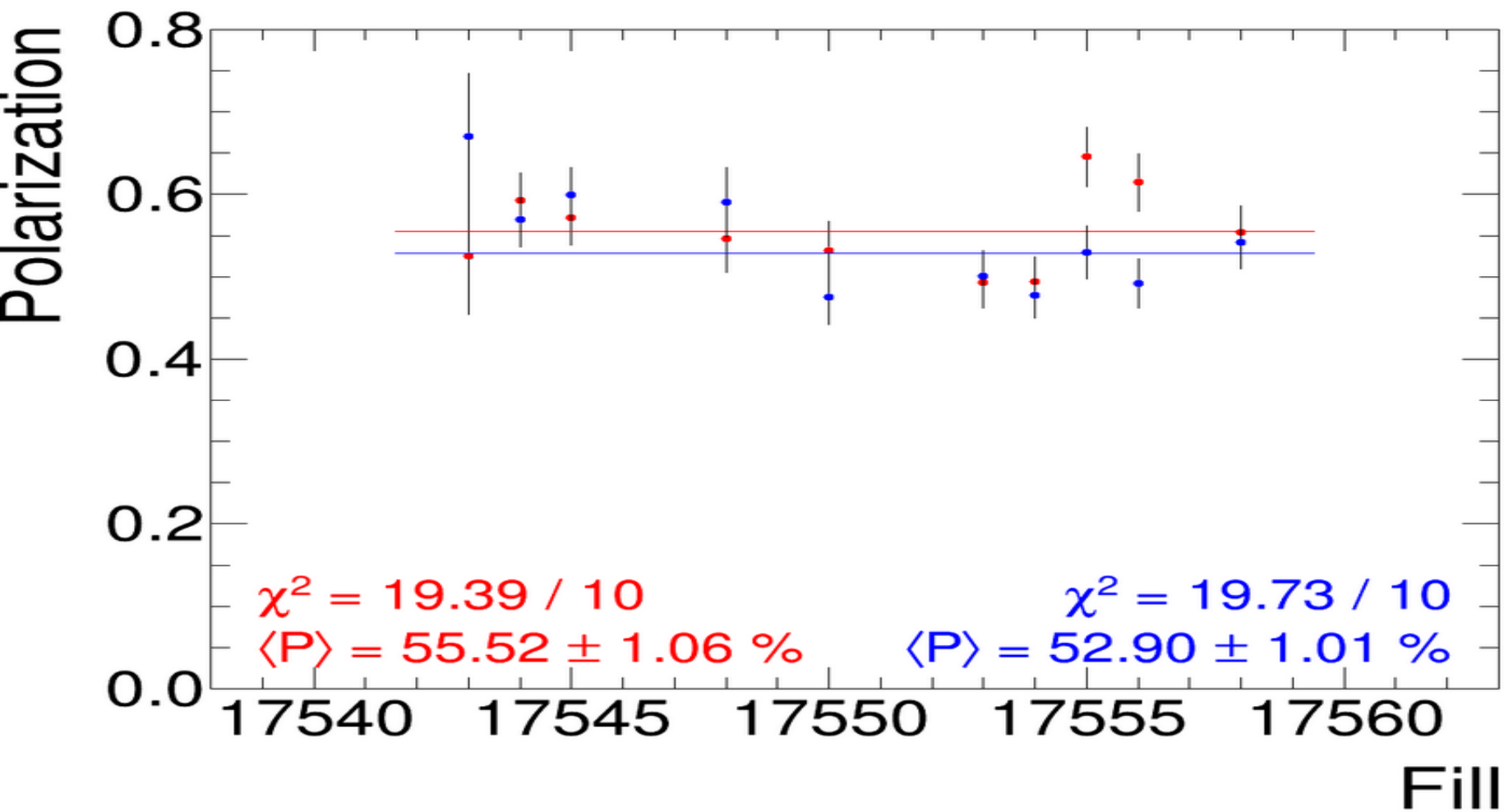
# "Golden fills" 17416-440



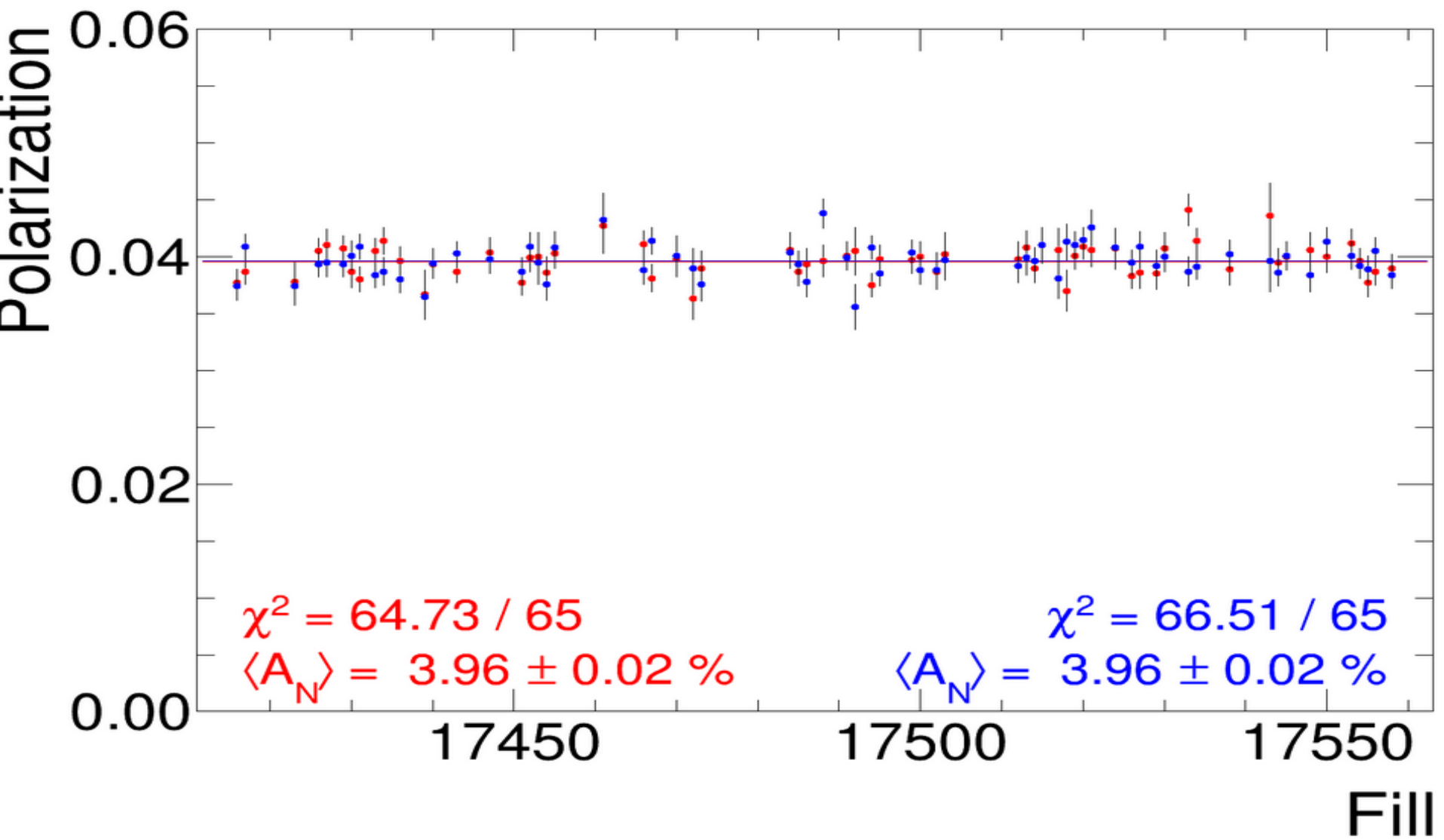
# H-jet polarization



# Fills 17543-58

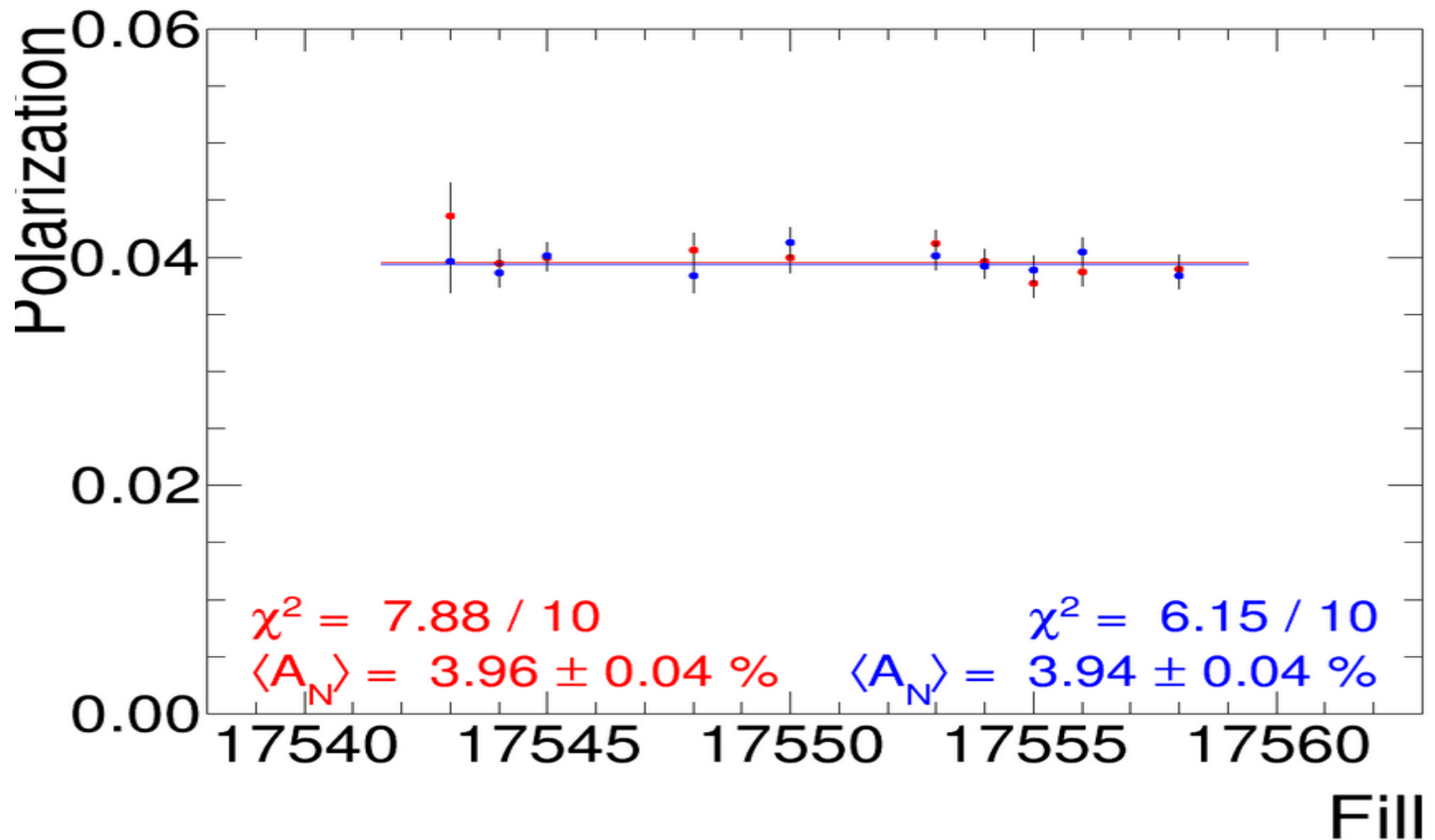


# H-jet analyzing power





# Fills 17543-58



# H-jet polarization measurements

05-16	17512	0.0398	+ -	0.0015	0.5665	+ -	0.0402	0.0392	+ -	0.0015	0.5820	+ -	0.0399
05-16	17513	0.0408	+ -	0.0015	0.5800	+ -	0.0403	0.0399	+ -	0.0015	0.5478	+ -	0.0392
05-17	17514	0.0390	+ -	0.0013	0.5278	+ -	0.0352	0.0396	+ -	0.0012	0.4900	+ -	0.0326
05-17	17515	0.0410	+ -	0.0016	0.4524	+ -	0.0393	0.0410	+ -	0.0016	0.5463	+ -	0.0414
05-17	17517	0.0406	+ -	0.0019	0.5866	+ -	0.0495	0.0381	+ -	0.0018	0.6538	+ -	0.0526
05-18	17518	0.0370	+ -	0.0018	0.5101	+ -	0.0495	0.0413	+ -	0.0016	0.5041	+ -	0.0414
05-18	17519	0.0401	+ -	0.0012	0.5729	+ -	0.0335	0.0410	+ -	0.0012	0.5317	+ -	0.0308
05-18	17520	0.0409	+ -	0.0011	0.5277	+ -	0.0294	0.0415	+ -	0.0011	0.4643	+ -	0.0279
05-19	17521	0.0406	+ -	0.0015	0.5820	+ -	0.0398	0.0426	+ -	0.0015	0.5307	+ -	0.0364
05-19	17524	0.0407	+ -	0.0018	0.5103	+ -	0.0456	0.0408	+ -	0.0017	0.4784	+ -	0.0438
05-20	17526	0.0383	+ -	0.0011	0.5707	+ -	0.0322	0.0395	+ -	0.0011	0.4964	+ -	0.0287
05-20	17527	0.0386	+ -	0.0014	0.5919	+ -	0.0388	0.0409	+ -	0.0013	0.5066	+ -	0.0341
05-20	17529	0.0385	+ -	0.0014	0.5707	+ -	0.0385	0.0392	+ -	0.0014	0.5088	+ -	0.0362
05-21	17530	0.0407	+ -	0.0014	0.5502	+ -	0.0360	0.0400	+ -	0.0013	0.5196	+ -	0.0350
05-21	17533	0.0441	+ -	0.0014	0.4878	+ -	0.0320	0.0387	+ -	0.0013	0.4680	+ -	0.0345
05-22	17534	0.0414	+ -	0.0011	0.5083	+ -	0.0280	0.0391	+ -	0.0011	0.5796	+ -	0.0301
05-23	17538	0.0389	+ -	0.0014	0.5631	+ -	0.0381	0.0402	+ -	0.0013	0.5191	+ -	0.0347
05-23	17543	0.0436	+ -	0.0029	0.5251	+ -	0.0705	0.0396	+ -	0.0027	0.6697	+ -	0.0773
05-24	17544	0.0395	+ -	0.0012	0.5923	+ -	0.0336	0.0386	+ -	0.0012	0.5695	+ -	0.0329
05-24	17545	0.0400	+ -	0.0012	0.5717	+ -	0.0335	0.0401	+ -	0.0012	0.5990	+ -	0.0337
05-25	17548	0.0406	+ -	0.0015	0.5463	+ -	0.0408	0.0384	+ -	0.0015	0.5902	+ -	0.0418
05-25	17550	0.0400	+ -	0.0014	0.5312	+ -	0.0364	0.0413	+ -	0.0013	0.4753	+ -	0.0337
05-26	17553	0.0412	+ -	0.0012	0.4927	+ -	0.0311	0.0401	+ -	0.0012	0.5009	+ -	0.0307
05-26	17554	0.0396	+ -	0.0011	0.4939	+ -	0.0301	0.0392	+ -	0.0011	0.4780	+ -	0.0284
05-26	17555	0.0377	+ -	0.0012	0.6454	+ -	0.0364	0.0389	+ -	0.0012	0.5294	+ -	0.0320
05-27	17556	0.0387	+ -	0.0012	0.6144	+ -	0.0346	0.0405	+ -	0.0012	0.4919	+ -	0.0298
05-27	17558	0.0390	+ -	0.0012	0.5535	+ -	0.0326	0.0384	+ -	0.0012	0.5412	+ -	0.0321

# pC-Fill summary

Fill	Type	Beam Energy, GeV	Start Time	Polarization, % In collisions			Polarization, % In collisions		
				Avrg.	P_0	Slope, %/h	Avrg.	P_0	Slope, %/h
<a href="#">17524</a>	phys	255	May 19, 2013 12:24:07 Sun	53.00 ± 3.49	54.25 ± 2.95	-0.57 ± 0.94	58.99 ± 4.42	59.38 ± 3.71	0.12 ± 1.20
<a href="#">17526</a>	phys	255	May 19, 2013 18:30:25 Sun	49.41 ± 2.74	48.91 ± 2.38	-0.57 ± 0.30	57.88 ± 3.80	55.20 ± 3.22	0.28 ± 0.40
<a href="#">17527</a>	phys	255	May 20, 2013 04:42:59 Mon	54.53 ± 3.34	54.44 ± 2.82	-0.64 ± 0.52	56.27 ± 3.71	54.78 ± 3.23	-0.20 ± 0.52
<a href="#">17529</a>	phys	255	May 20, 2013 13:57:43 Mon	47.16 ± 2.20	56.69 ± 2.00	-1.80 ± 0.24	57.17 ± 3.71	57.00 ± 3.20	-0.41 ± 0.41
<a href="#">17530</a>	phys	255	May 21, 2013 00:07:45 Tue	53.80 ± 2.98	55.47 ± 2.48	-0.31 ± 0.47	56.51 ± 4.01	52.89 ± 3.38	0.35 ± 0.60
<a href="#">17533</a>	phys	255	May 21, 2013 13:52:37 Tue	52.39 ± 3.53	52.04 ± 3.04	-0.56 ± 0.50	57.44 ± 4.10	61.02 ± 3.53	-0.16 ± 0.58
<a href="#">17534</a>	phys	255	May 21, 2013 22:02:41 Tue	57.87 ± 3.03	59.67 ± 2.53	-0.22 ± 0.31	54.51 ± 3.53	50.06 ± 2.97	0.38 ± 0.34
<a href="#">17543</a>	phys	255	May 23, 2013 15:02:36 Thu	55.35 ± 2.51	55.76 ± 2.46	0.48 ± 2.31	57.75 ± 3.76	55.44 ± 3.61	1.34 ± 2.70
<a href="#">17544</a>	phys	255	May 23, 2013 18:44:11 Thu	54.53 ± 2.42	52.63 ± 2.04	0.49 ± 0.27	55.30 ± 2.38	51.11 ± 2.02	0.18 ± 0.27
<a href="#">17545</a>	phys	255	May 24, 2013 05:56:43 Fri	53.86 ± 3.61	51.76 ± 3.26	0.15 ± 0.61	58.89 ± 2.90	59.86 ± 2.35	-0.08 ± 0.40
<a href="#">17548</a>	phys	255	May 24, 2013 19:33:26 Fri	53.35 ± 3.68	51.86 ± 2.89	0.07 ± 0.81	63.09 ± 4.68	62.87 ± 3.63	-0.18 ± 1.07
<a href="#">17550</a>	phys	255	May 25, 2013 04:00:39 Sat	52.60 ± 2.98	51.77 ± 2.34	-0.10 ± 0.39	58.06 ± 3.50	57.78 ± 2.57	0.19 ± 0.50
<a href="#">17553</a>	phys	255	May 25, 2013 16:54:57 Sat	53.17 ± 2.68	55.39 ± 2.33	-0.53 ± 0.31	55.19 ± 2.76	55.17 ± 2.32	-0.06 ± 0.33
<a href="#">17554</a>	phys	255	May 26, 2013 02:31:02 Sun	50.81 ± 2.84	53.74 ± 2.41	-0.73 ± 0.32	50.50 ± 2.82	55.00 ± 2.33	-1.02 ± 0.33
<a href="#">17555</a>	phys	255	May 26, 2013 13:24:55 Sun	51.69 ± 2.88	48.55 ± 2.53	-0.18 ± 0.31	57.57 ± 2.39	62.76 ± 1.98	-0.04 ± 0.29
<a href="#">17556</a>	phys	255	May 26, 2013 23:01:20 Sun	55.76 ± 3.21	58.72 ± 2.77	-0.17 ± 0.37	56.26 ± 2.39	56.44 ± 2.00	-0.03 ± 0.29