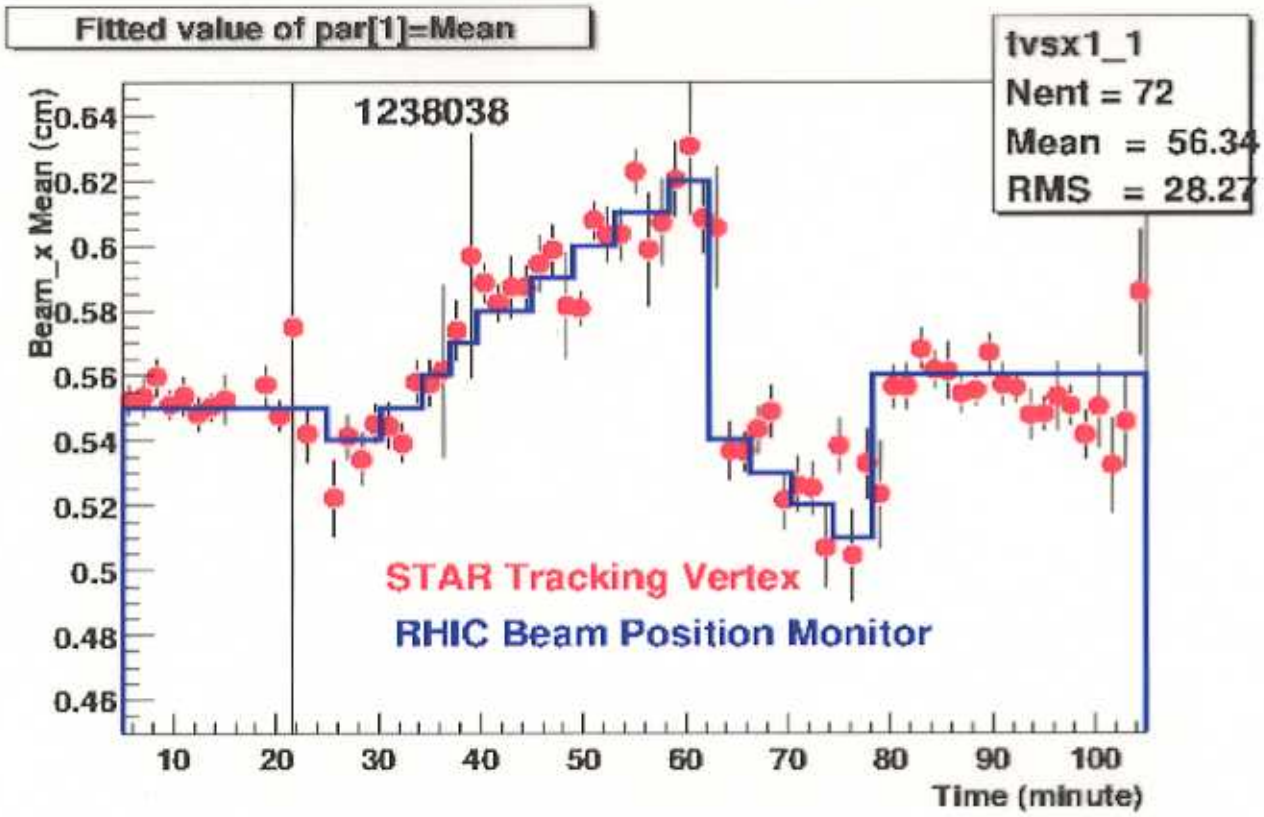
What are Vernier Scans?

Van–der–Meer Scans or Vernier Scans are done by stepwise sweeping one beam across the other while measuring collision rates as a function of beam displacement. This is done in both planes.

Needed basic instrumentation: the ZDCs or other collision monitors (BBC ...) at the various IRs, corrector magnet control to apply 4–bump at IR, DX Beam Position Monitors (BPM) and beam current measurements from Wall Current Monitor (WCM).

A Gauss function is fitted to the result yielding the maximum rates (R_x^{max}, R_y^{max}) the location of the maximums (x_{max}, y_{max}) and the effective beam widths (σ_x, σ_y) in both planes.

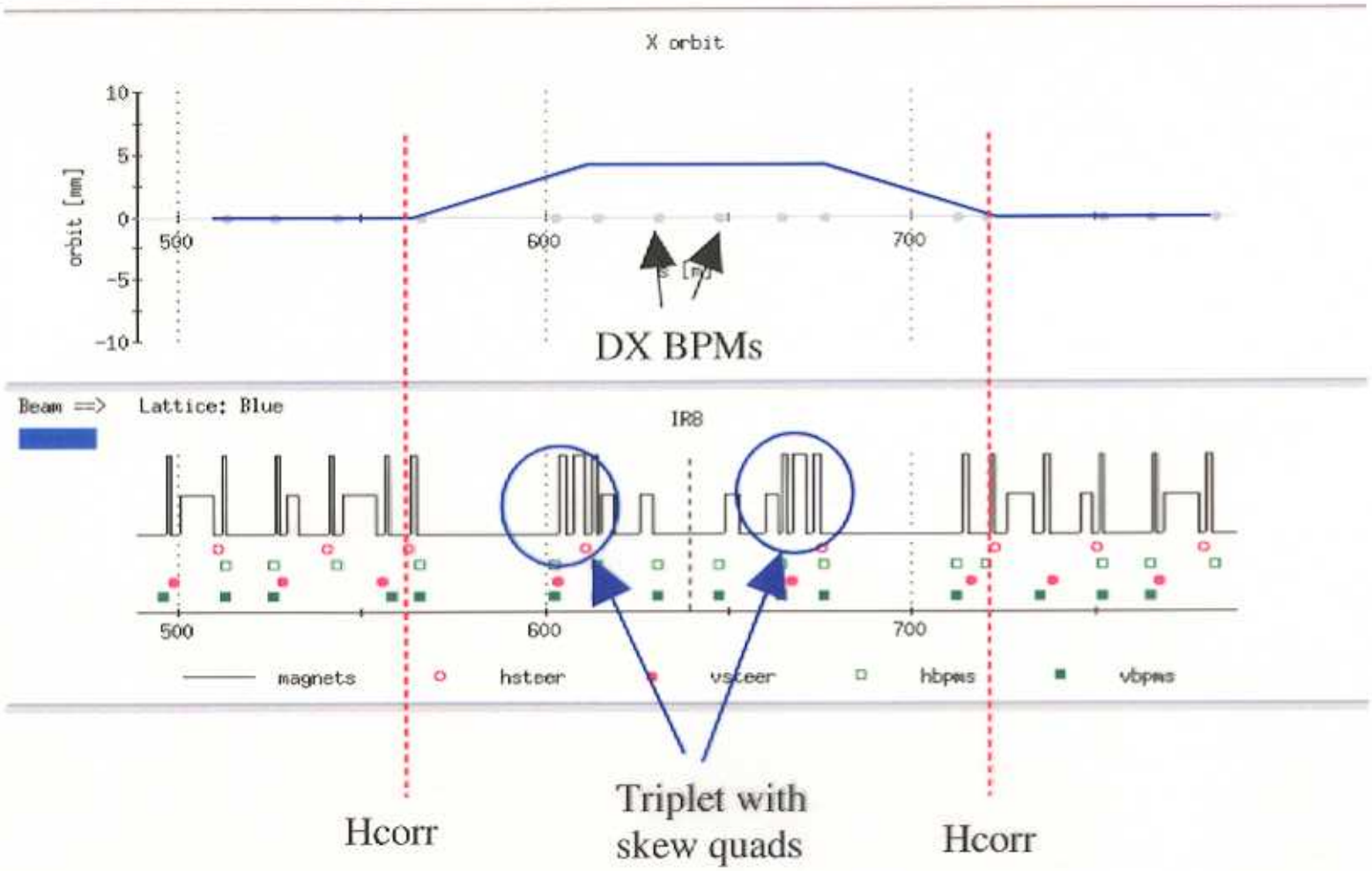
The Method



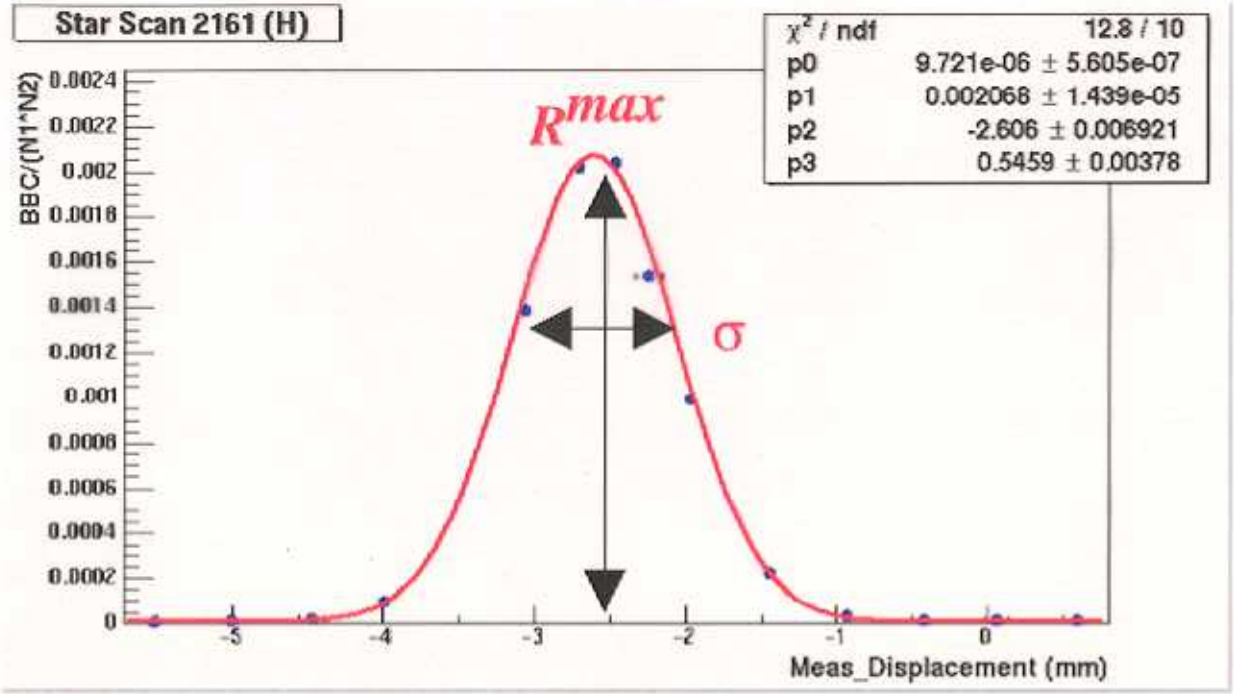
STAR reconstructed vertex during a horizontal scan in 2000 (arbitrary offset added to adjust both data sets).

- **Sweeping blue or yellow beam**
- **Stepsize: 100–500 μm**
- **approx. 2 min./point**
- **good agreement with STAR data**

Method: IR bumps



- New since 2001–02: skew quads in triplets!
- Different optics (β^*) requires different corrector settings.
- Only one beam is moved per scan



- do both planes (varying order)
- approx. 30 min. / scan
- fit Gauss function to data
- reasonable c2/ndf
- get fit parameters to calculate luminosity and cross section

$$\sigma_{(BBC)} = R^{max}\ 2\pi\sigma_x\sigma_y k_b/f_{rev}$$

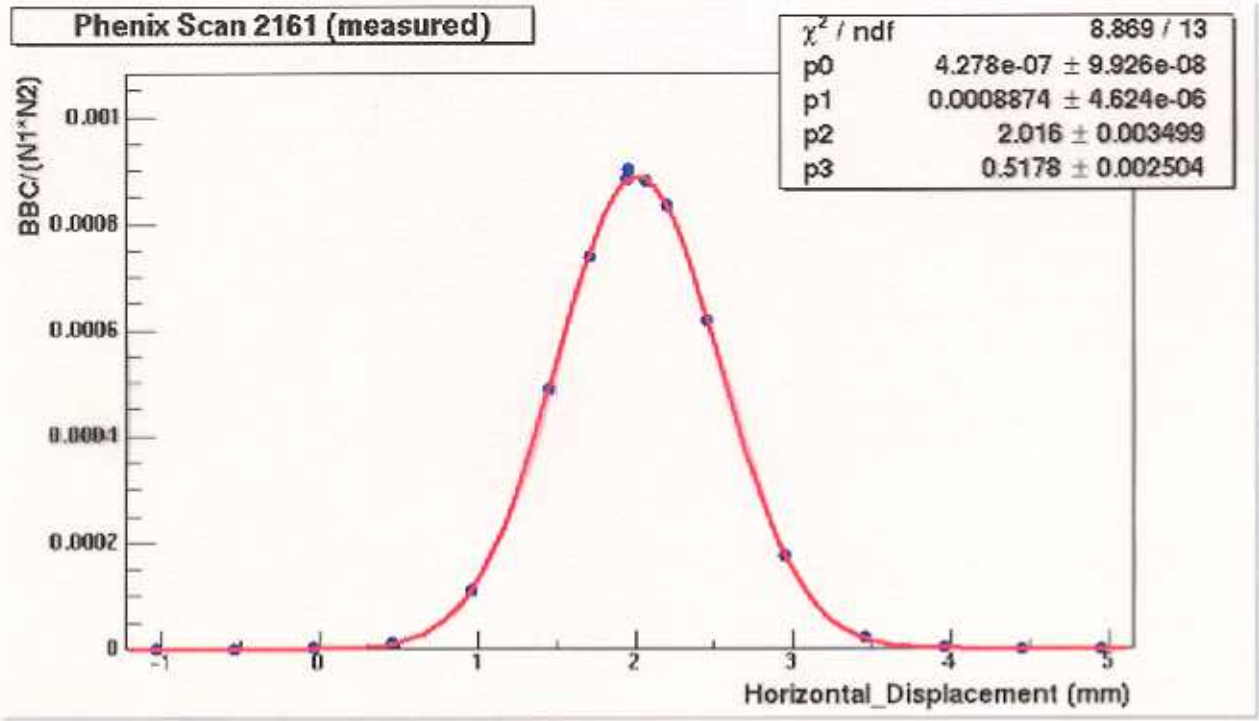
$\sigma_x\ \sigma_y$: horz./vert. profiles

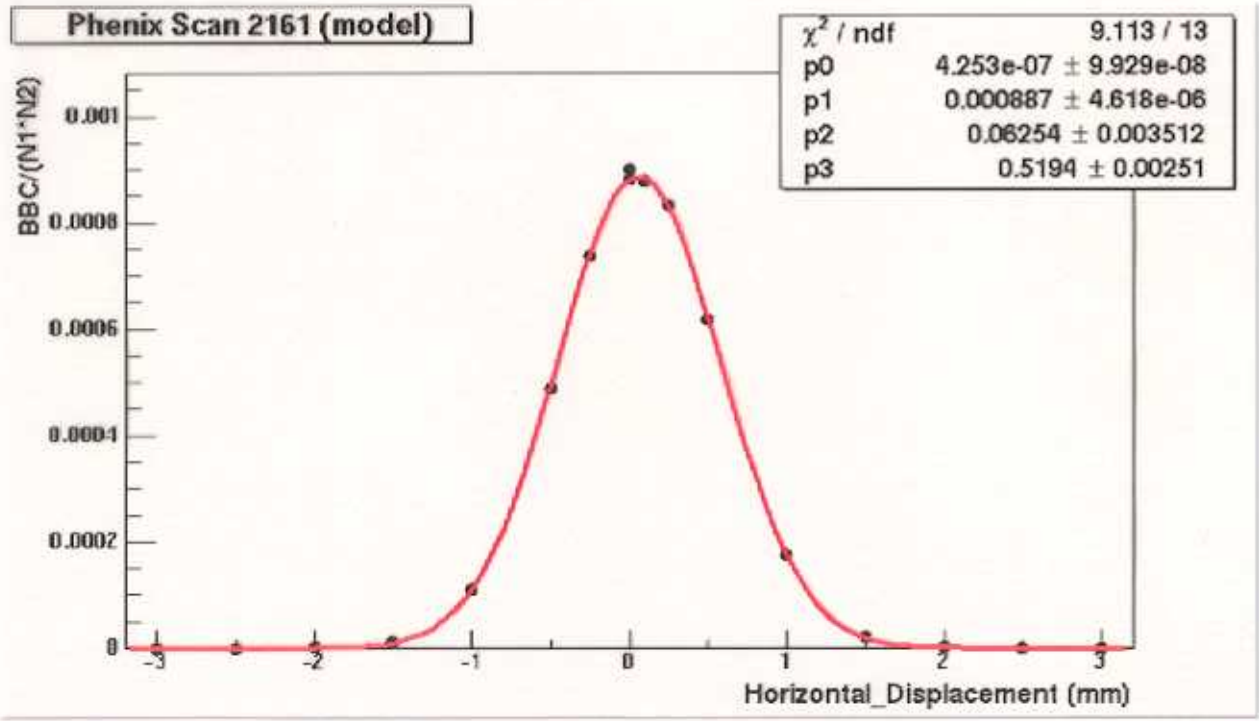
k_b : number of bunches

f_{rev} : revolution frequency

Available Data from Scans in run pp_fy02

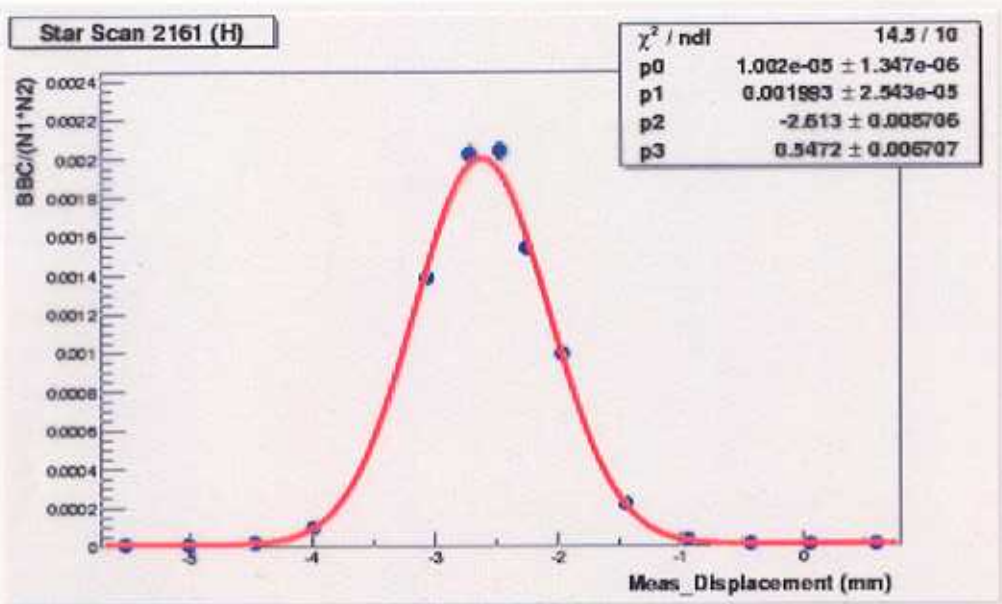
Fill number	IR	date	$\beta*$	comment
2119	STAR	12/30/01	3 m	horiz. only, no ZDC
2136	PHENIX	1/3/02	3 m	no ZDC
2161	STAR	1/6/02	3 m	
2161	PHENIX	1/6/02	3 m	
2193	STAR	1/10/02	3 m	no bpm
2193	IR2	1/11/02	3 m	one side bpm
2233	IR2	1/15/02	3 m	one side bpm
2277	STAR	1/20/02	3 m	
2277	PHENIX	1/20/02	3 m	

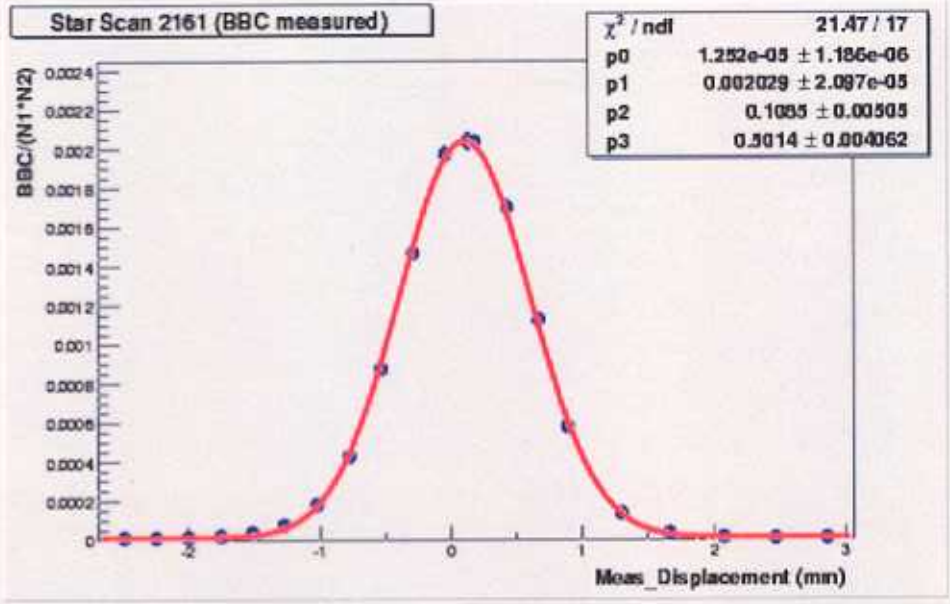


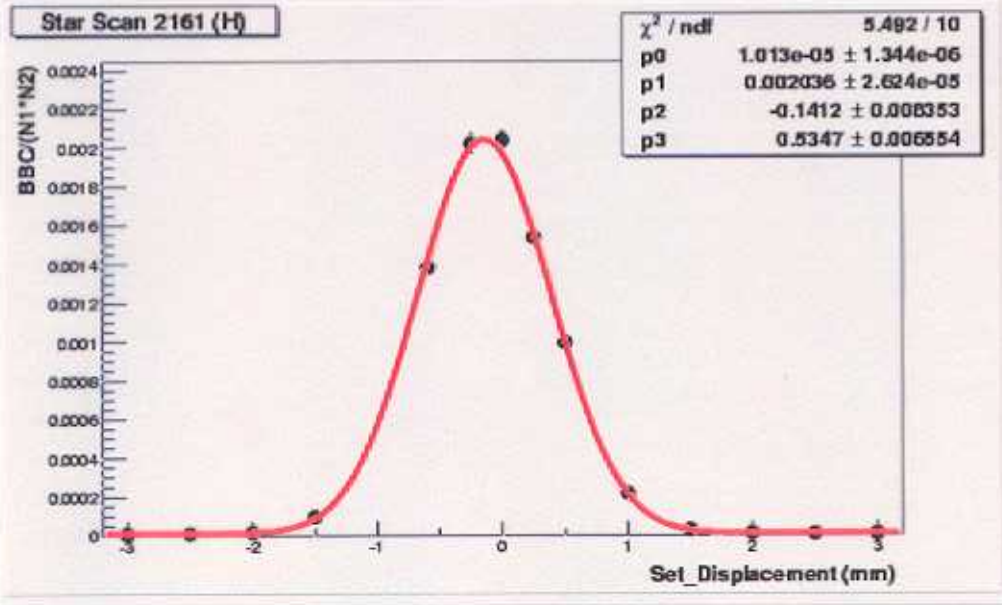


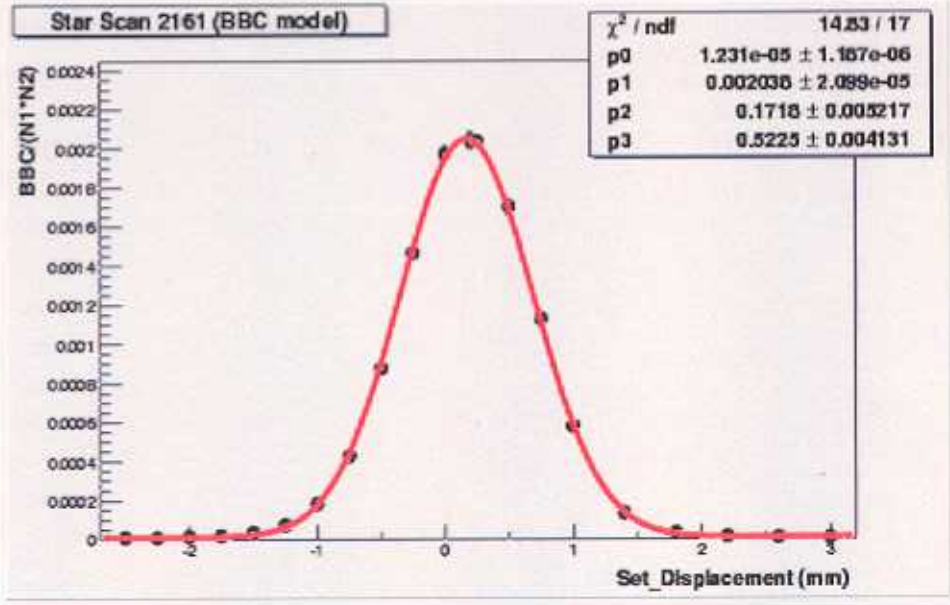
Fill 2161
Horizontal scan
Yellow beam moved

STAR PP scan 2161:

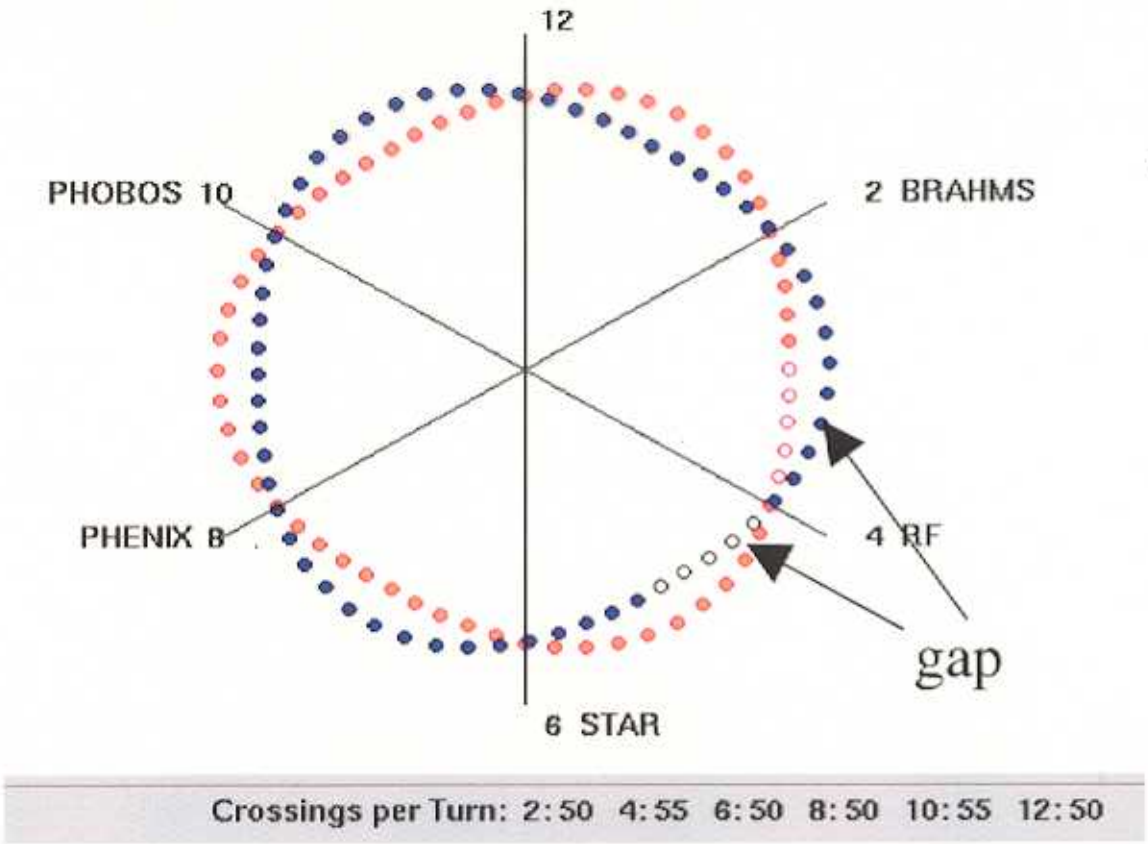








Correction: Fill Pattern

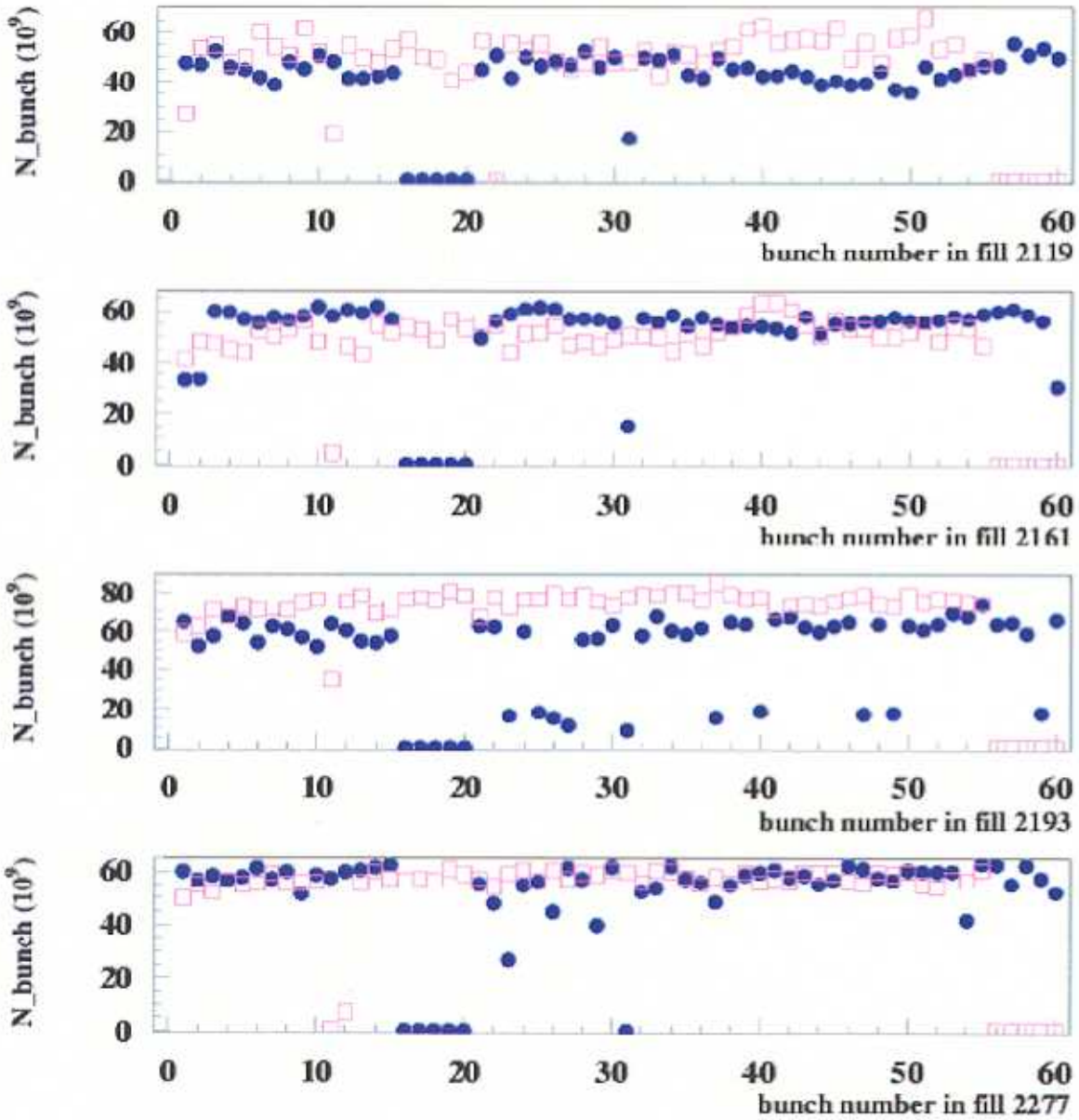


- Total beam current has to be corrected for actual colliding pairs of bunches at the IRs.

- With 55 bunches (and 60 bunch pattern) this is 9% (5 out of 55) at all IPs except IR8 and IR2 (Au–Au) or IR4 and IR10 (pp). Correction varies from fill to fill slightly.

colliding bunch pairs in STAR

correction:

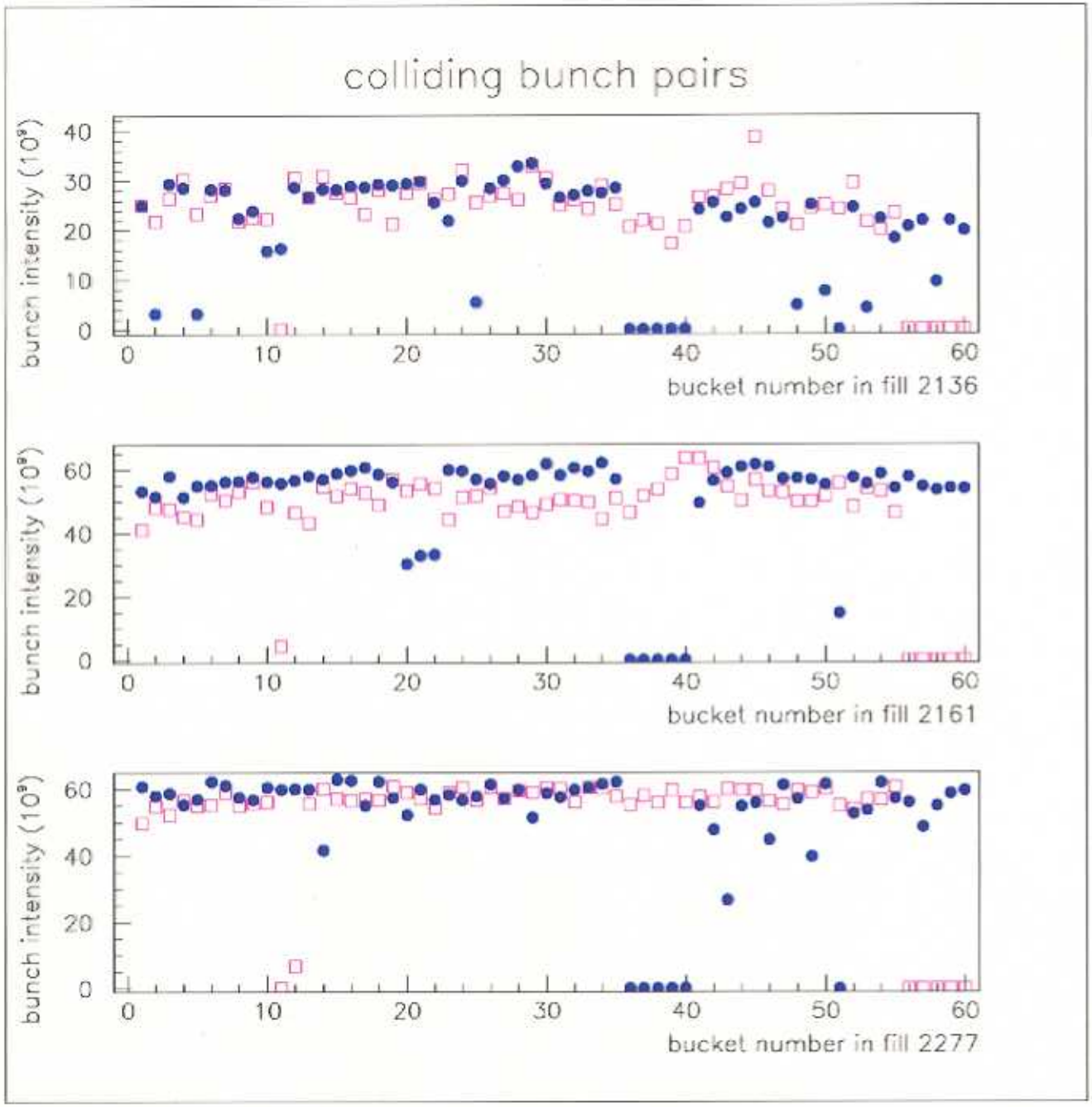


0.90

0.91

0.90

0.90

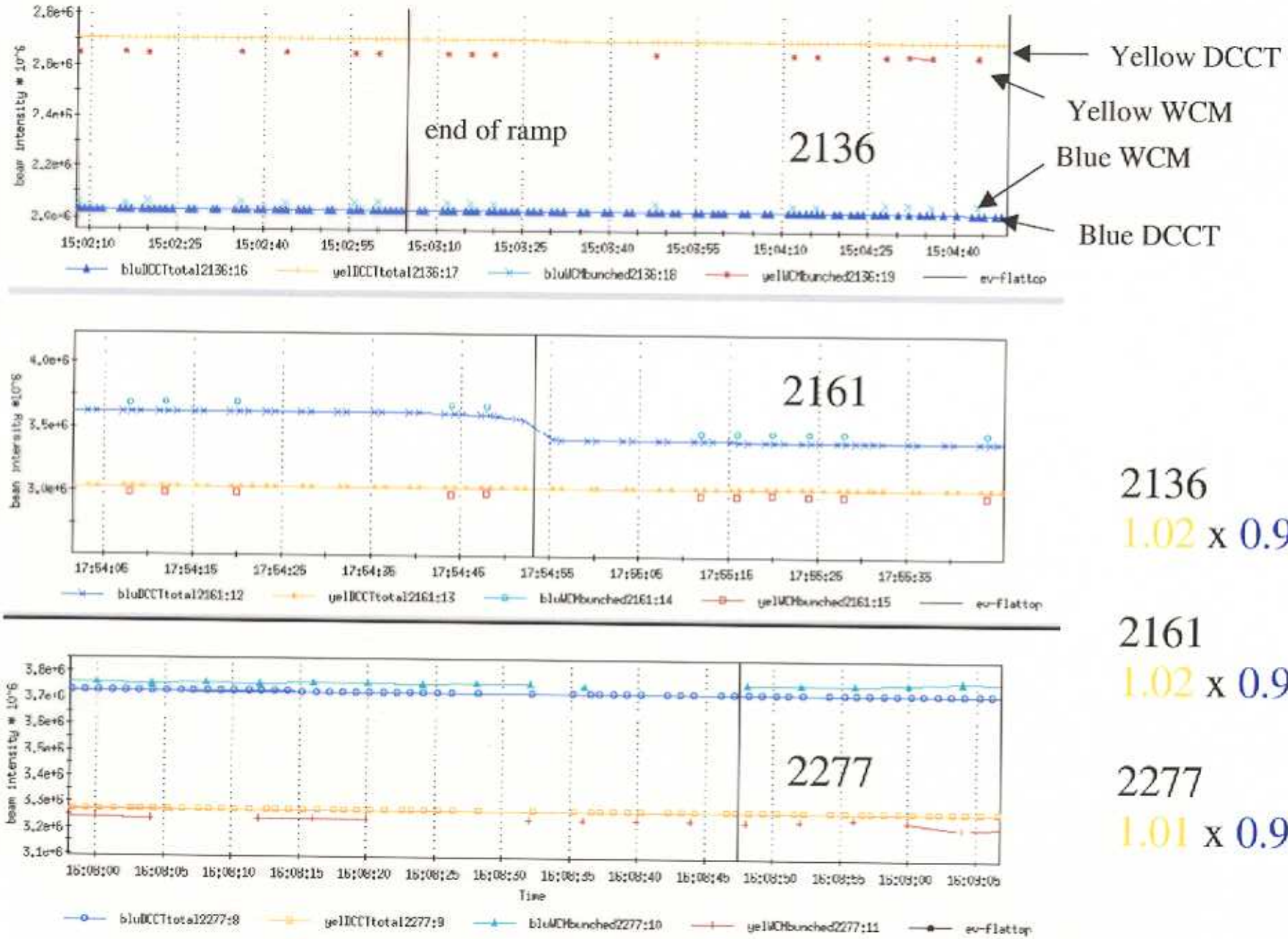


2136
0.97

2161
0.90

2277
0.90

Beam Current Measurements and Errors:



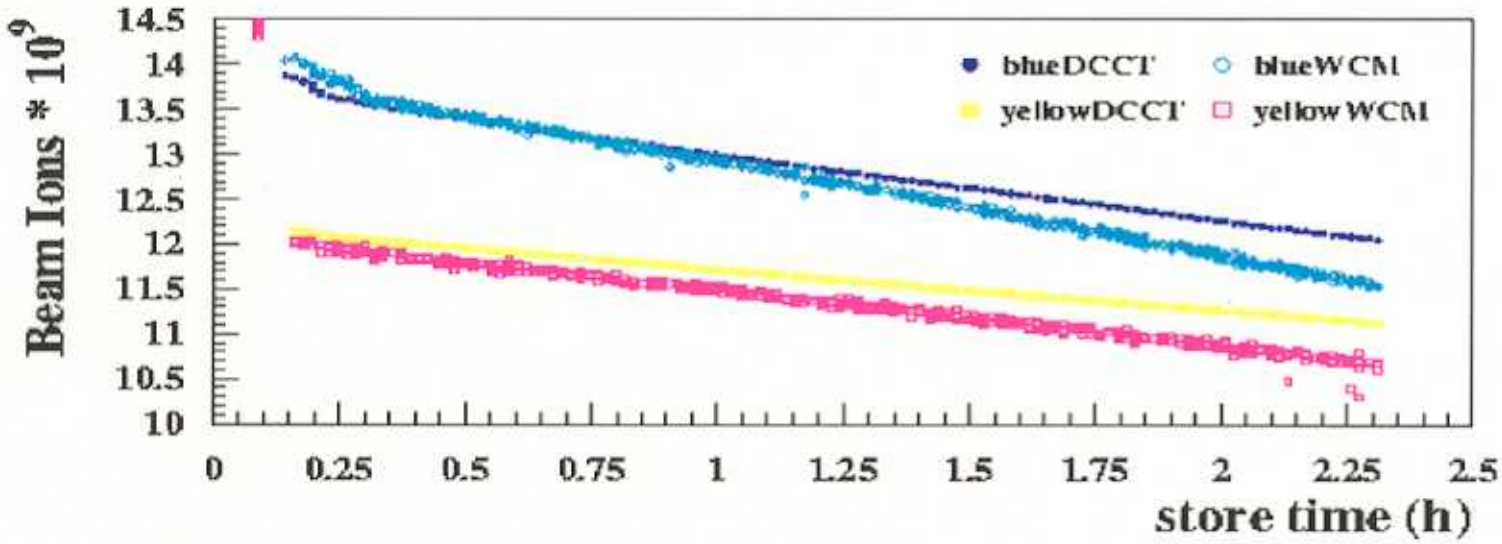
2136
1.02 x 0.98

2161
1.02 x 0.98

2277
1.01 x 0.99

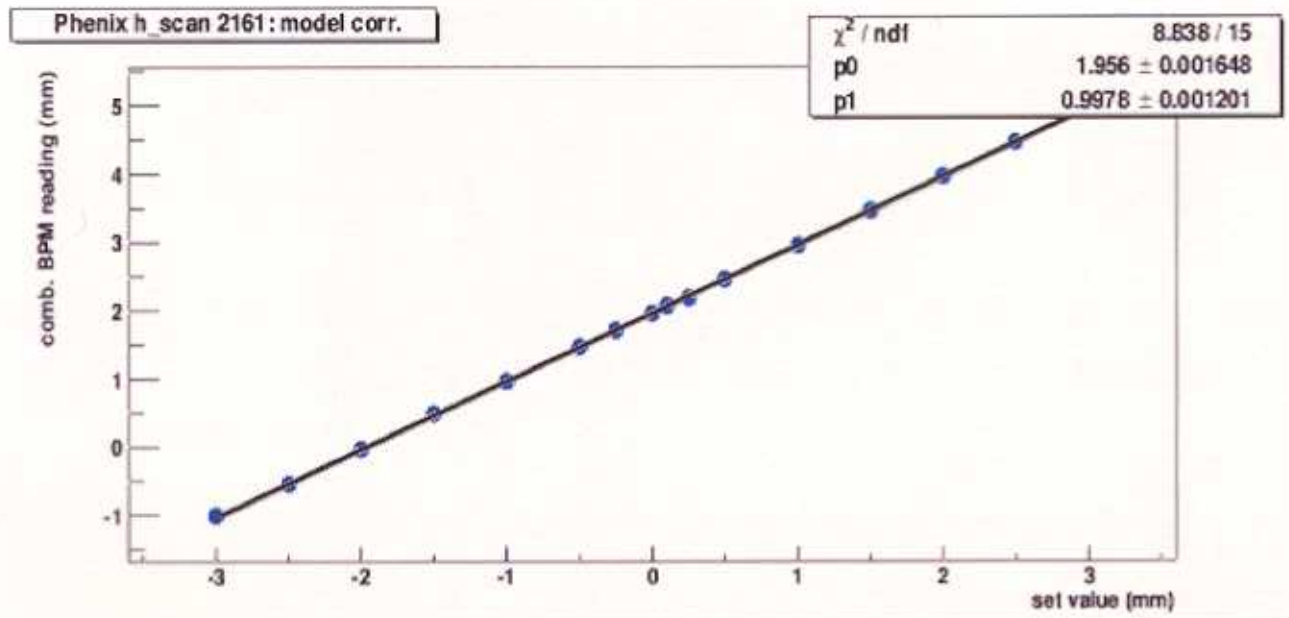
Analysis: The WCM

WCM and DCCT readings during a store as fct. of time

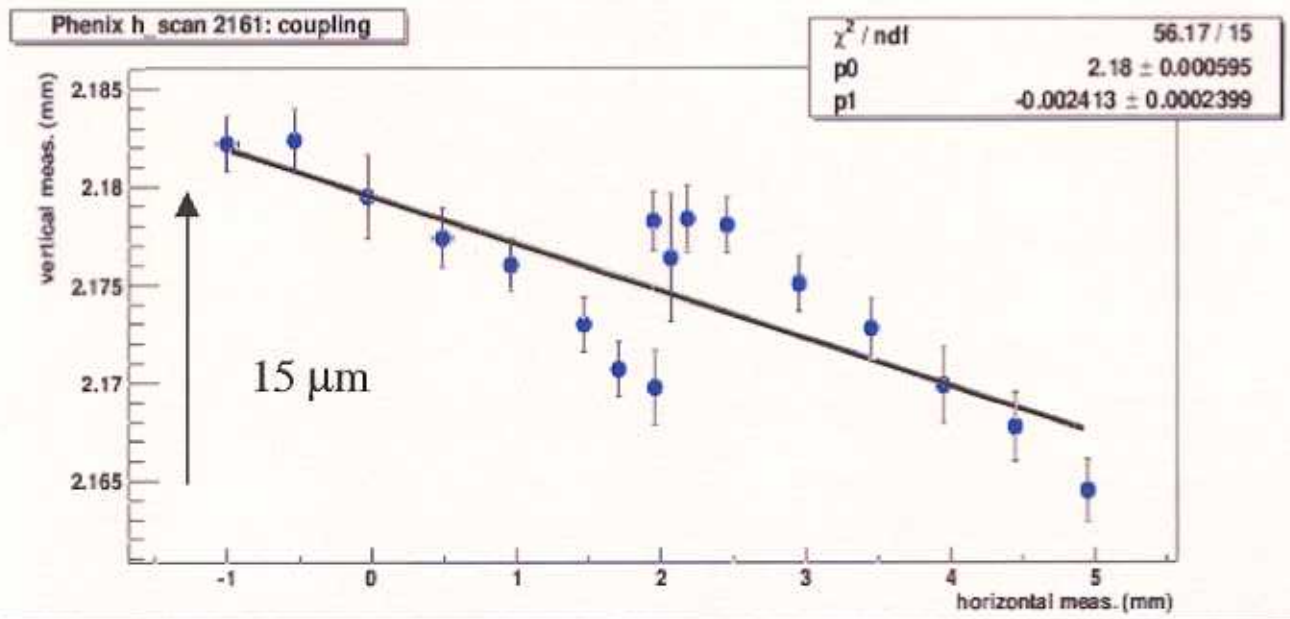


- ★DCCT: accurate (0.2%) device to measure ANY coasting beam in RHIC
- ★WCM : measures **BUNCHED** beam only
- ★Calibrate WCM with DCCT at beginning of store only
- ★Observed deviation around 2 –**3%**

Coupling and Model Corrections at PHENIX



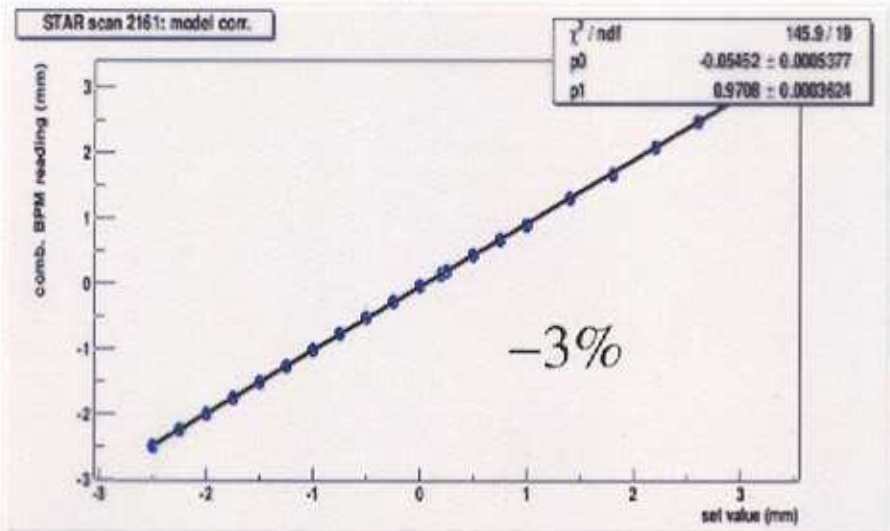
meas. vs. model (set) used for consistency check

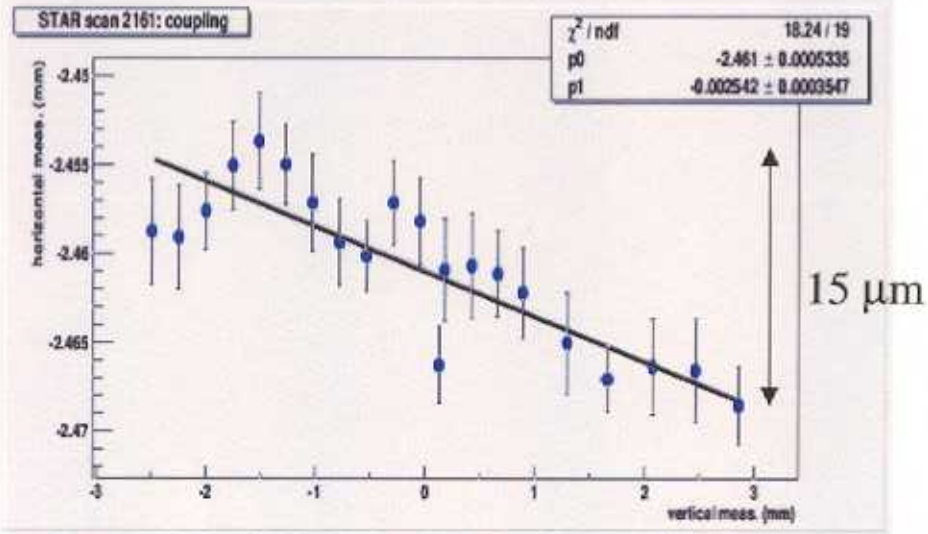


"cross talk", i.e. movement in v–plane while moving in h–plane, is corrected for

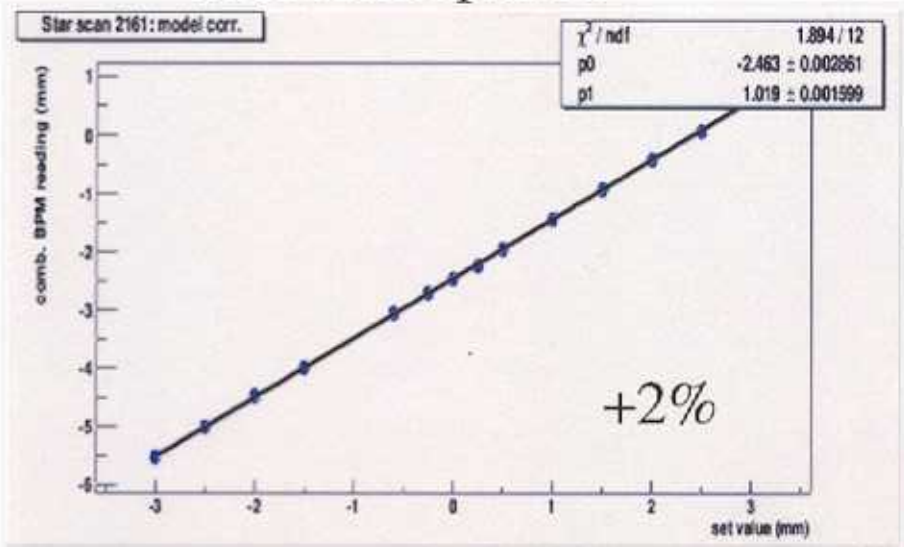
Coupling and Model corrections STAR scan 2161

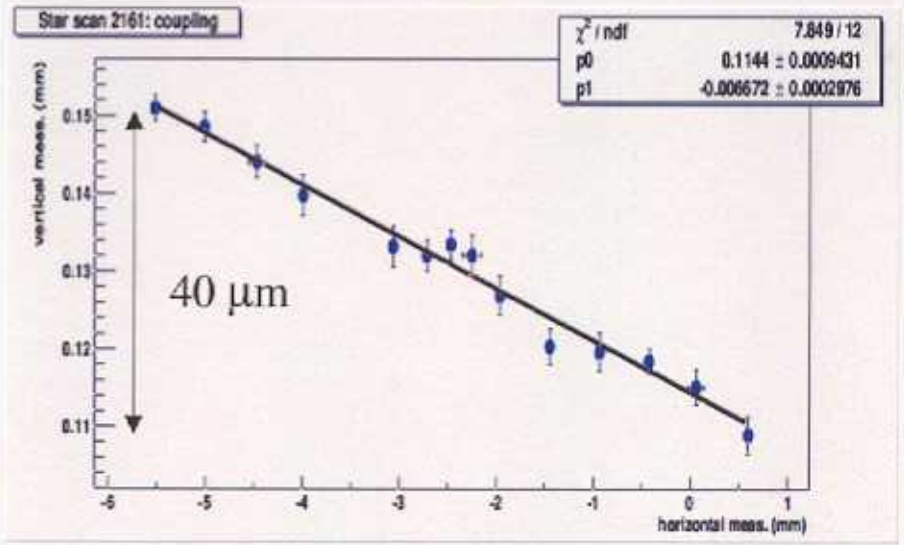
vertical plane:





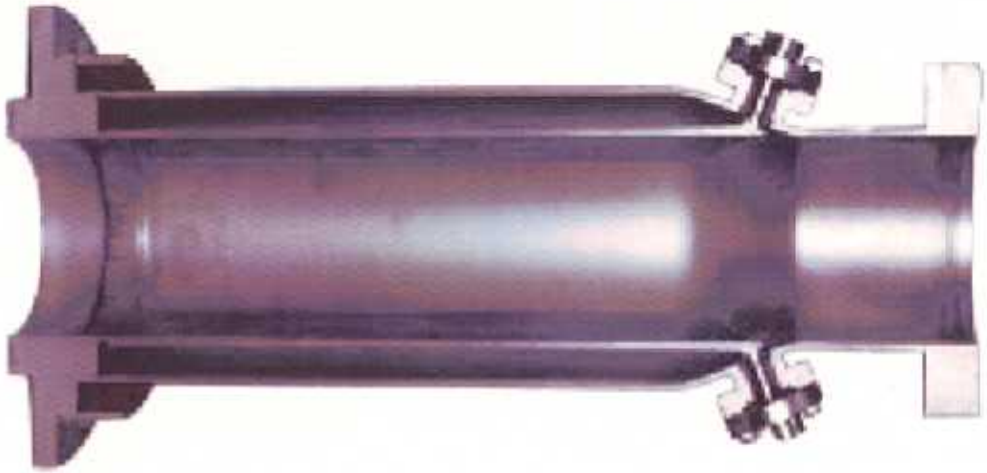
horizontal plane:

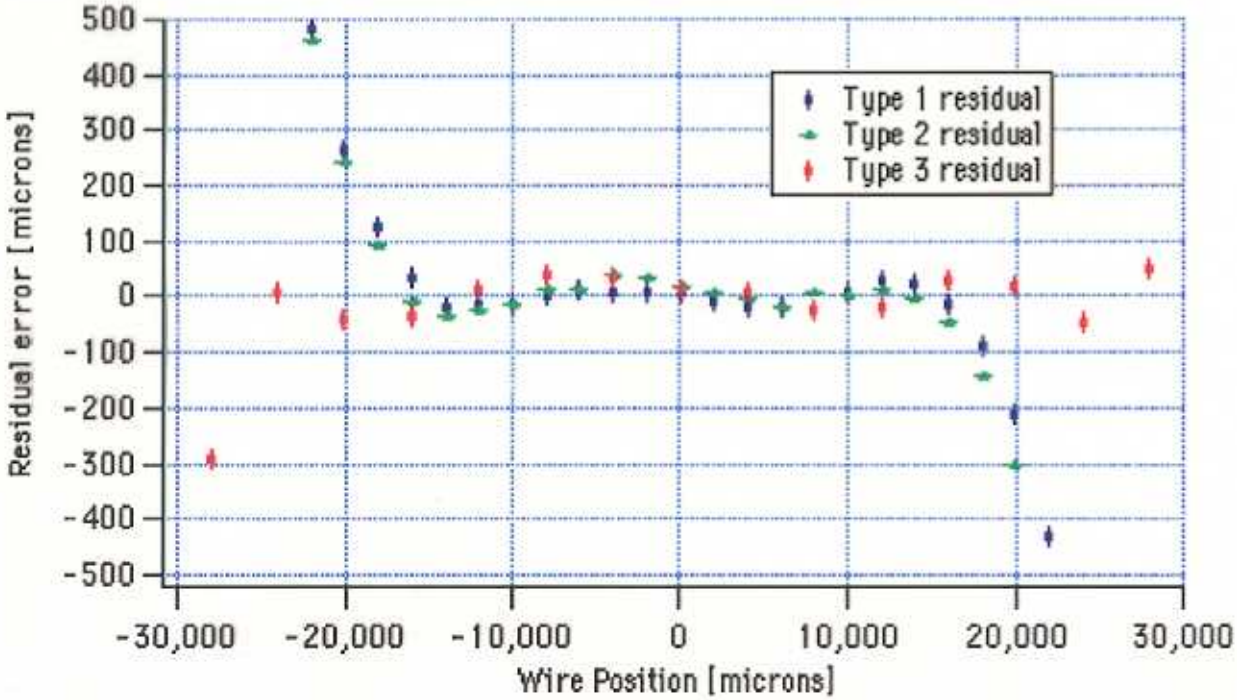




BPM precision/resolution

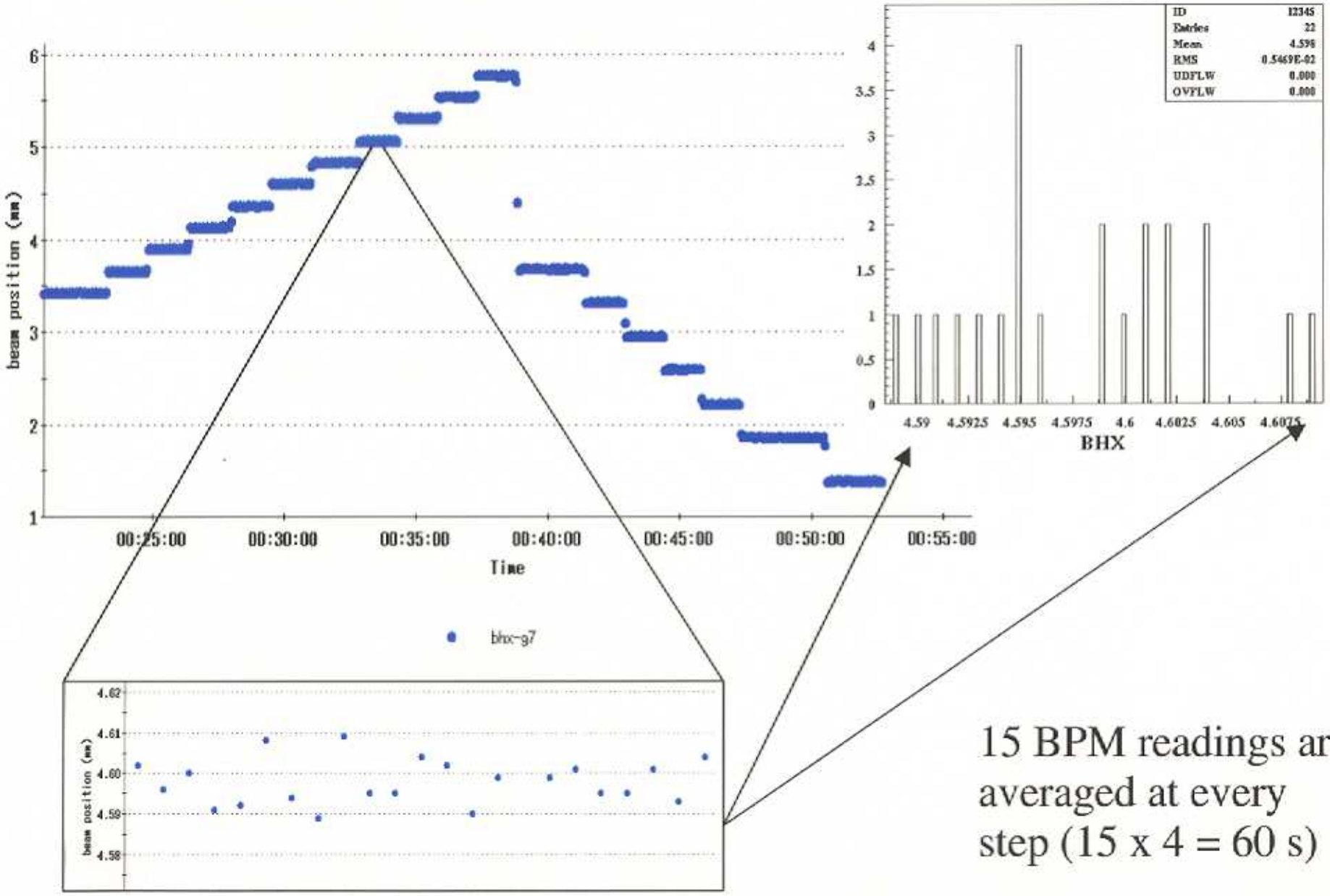
DX BPMS: type2
Dual plane
Small aperture





An absolute error of 2% is added

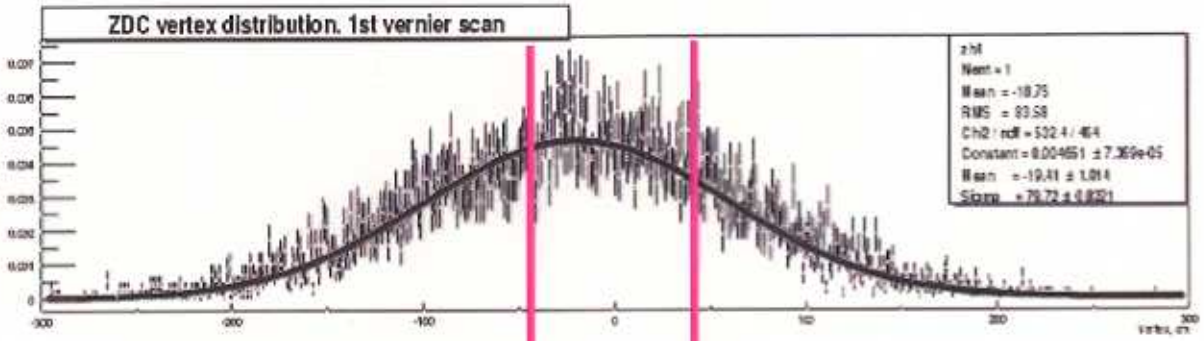
BPM resolution



15 BPM readings are averaged at every step (15 x 4 = 60 s)

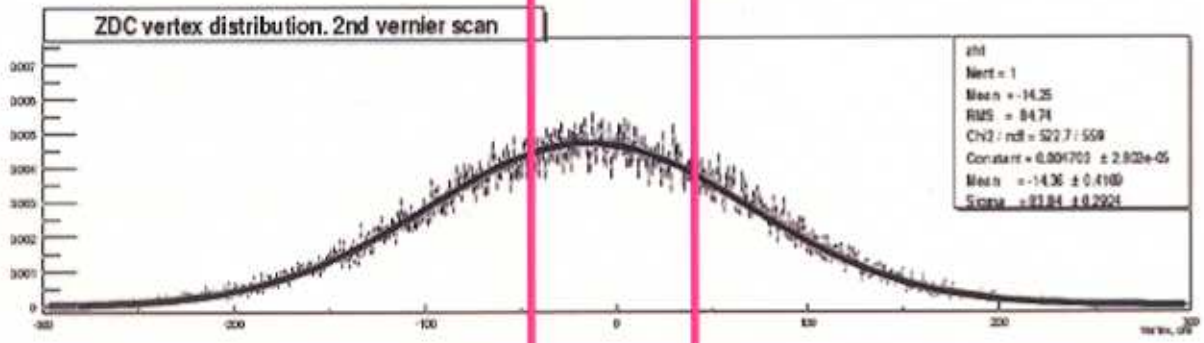
Scaling 75cm–>30cm & ZDC normalization

2136



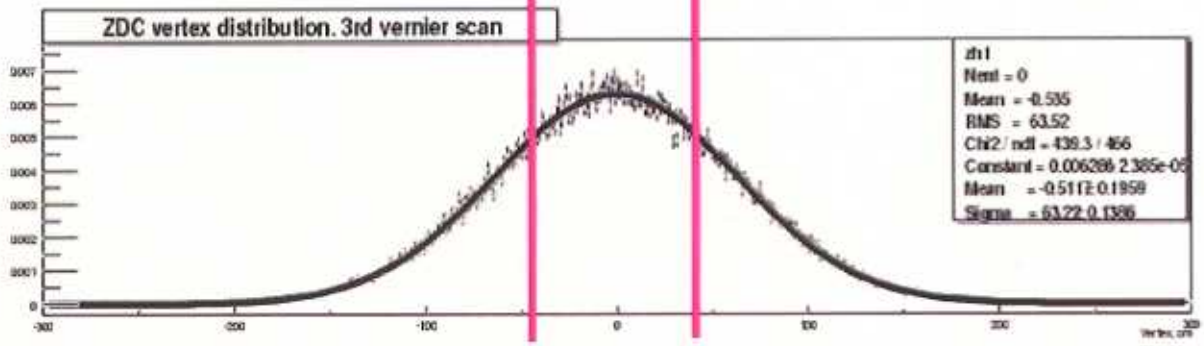
0.466 +/– 0.006
0.281 +/– 0.007

2161



0.459 +/– 0.002
0.271 +/– 0.003

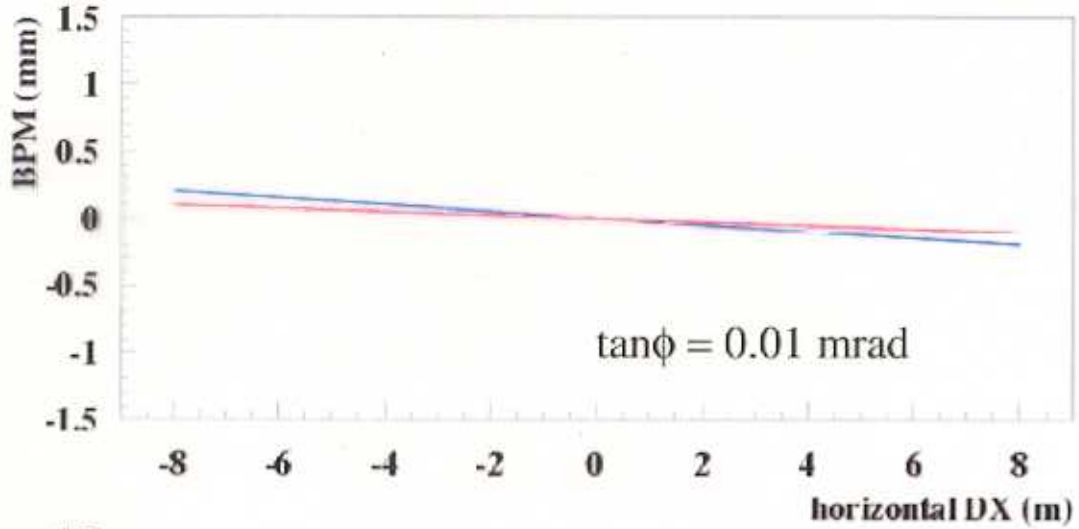
2277

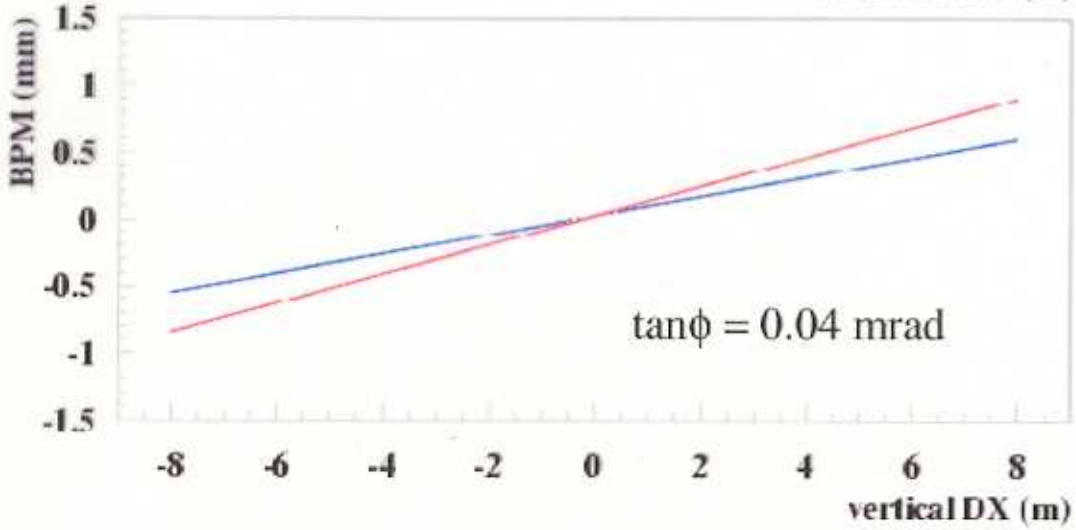


0.497 +/– 0.003
0.364 +/– 0.001

PHENIX data are used to scale from 75 cm–> 30cm
and to normalize to the cross section as seen by the ZDC

PHENIX crossing angle fill 2277





Correction for crossing angles:

$$R = \sqrt{1 + \left(\frac{\sigma_z}{\sigma_x} \tan\phi\right)^2}$$

tanϕ : ½ cross. angle

σ_Z: long. bunch profile 1m (avg.)

σ_X: horiz. bunch profile 360 μm (avg.)

tanϕ = 0.1 mrad R=1.01

tanϕ = 0.2 mrad R=1.04

tanϕ = 0.5 mrad R=1.20

Data taken after vernier scan (no transv. offsets)

Adjusted by 0.–0.4 mm to cross at 0/0 –> uncertainty of 0.1 mrad

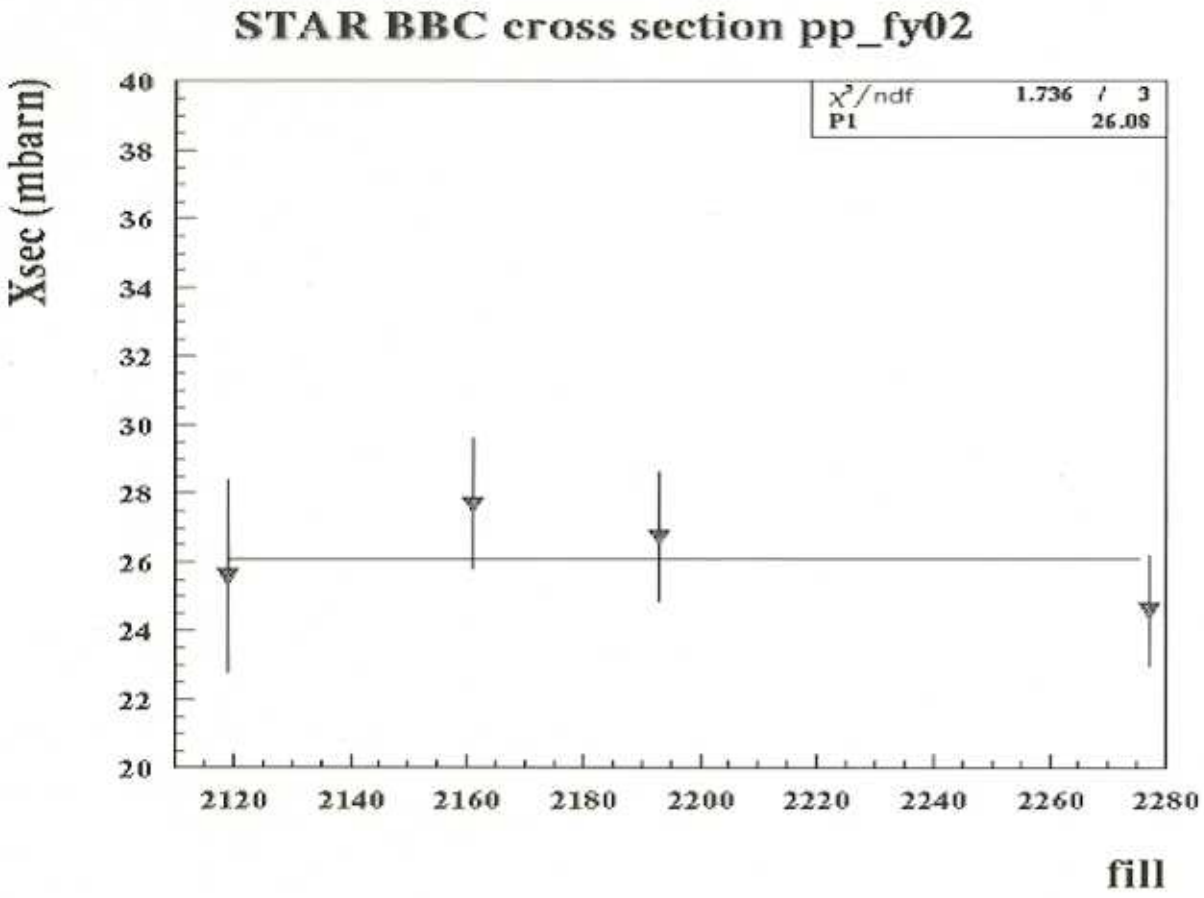
Systematic Errors and Final Corrections

BPM scatter	BC calibration x2	Crossing angle	Scaling 75–>30 cm	Abs. BPM	Blow up
3%	1.4–2.8%	1%	1%	2%	1%

Point to point absolute

fill	σ(BBC) (mbarn)	Fill patt.	Cross. angle	Scale factor	σ(BBC) +/–30cm	Stat.	Syst.
2136	11.7	0.97 −1	+0.2	1.66	20.4	0.2	1.3
2161	11.7	0.90 −1	–	1.7	22.1	0.2	1.4
2277	15.4	0.90 −1	–	1.38	23.6	0.1	1.0

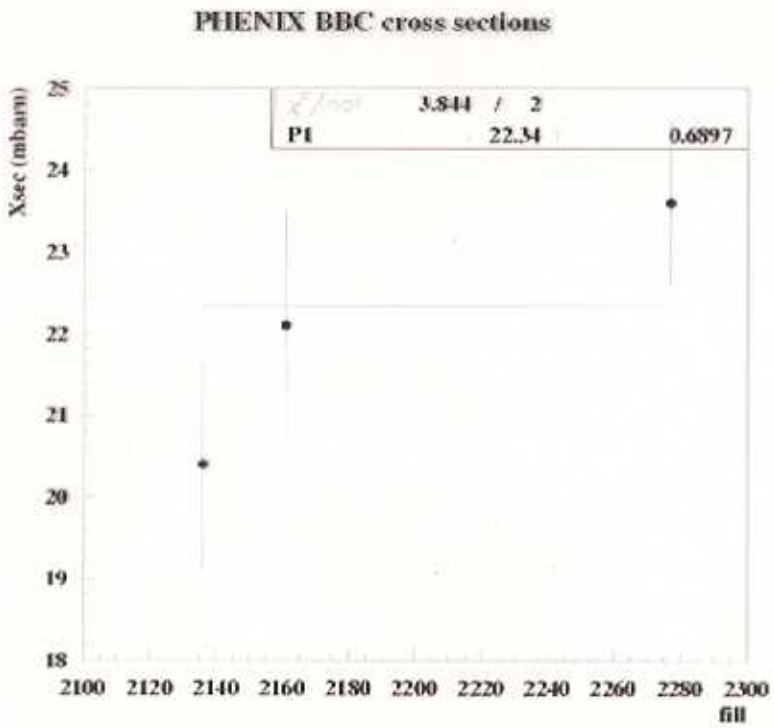
STAR



stat. & syst. errors!!

$\sigma_{BBC,STAR}$ = 26.1 +/– 0.2 (stat) +/– 1 (syst.) +/– 0.8 (abs.) mbarn

Summary: BBC$^{+/-\ 30\ cm}$ Cross Section



Total inelastic cross section
World average:
42.2 +/– 1.9 mbarn

BBC cross section is 53%
(consistent with simulations)

Final number after all corrections:

$\sigma_{BBC,+/-30\ cm}$ = 22.3 +/– 0.1 (stat) +/– 0.6 (syst) +/– 0.7 (abs.)