



Track-based endcap alignment

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1. Photogrammetry: x, y, z, ϕ_x (some of which are bigger than 2 mrad), ϕ_z
2. Disk-bending from hardware: additional correction on ϕ_x and ring radii
3. Small additional-additional correction on ring radii to set closure = 0
4. Beam-halo + PG x, ϕ_z at the level of *disks*
5. globalMuon *disk*-alignment in global x, y, ϕ_z (future)
6. final global z corrections for *disks*? (future)



- ▶ Applied in the right direction (bottoms of chambers go toward I.P.)
- ▶ But photogrammetry spread in values is larger than this change

ME+1/1	0.002	ME-1/1	0.002
ME+1/2	0.002	ME-1/2	0.002
ME+1/3	0.002	ME-1/3	0.002
ME+2/1	0.00239	ME-2/1	0.00261
ME+2/2	0.00273	ME-2/2	0.00303
ME+3/1	0.00230	ME-3/1	0.00237
ME+3/2	0.00263	ME-3/2	0.00288
ME+4/1	0.00208	ME-4/1	0.00221
ME+4/2	0.002	ME-4/2	0.002

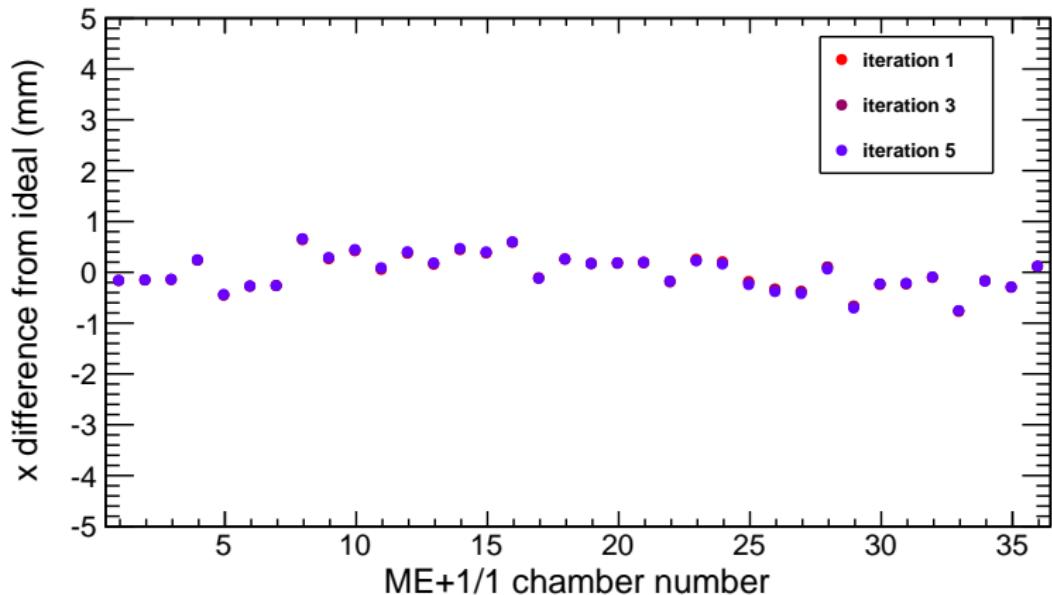
- ▶ The numbers (rad):
 - ▶ The 3-sig-fig numbers are from Oleg
 - ▶ The “0.002” are an approximation for the rest
 - ▶ Ring-radius corrections = $(\phi_x) \times (\text{dist from chamber center to disk center})$
 - ▶ “disk center” rather than “disk surface” is an update that significantly improves hardware/track ring-radius agreement (the missing factor of 2)

- ▶ After the expected correction from disk-bending geometry, we apply another ring-radius correction to make beam-halo closure zero

Ring	radius change	closure/chamber (before)
ME+1/1	-0.64 mm	-0.11 mm
ME+1/2	+0.60 mm	+0.10 mm
ME+2/1	+0.37 mm	+0.13 mm
ME+2/2	-1.75 mm	-0.31 mm
ME+3/1	+0.33 mm	+0.12 mm
ME+3/2	-1.52 mm	-0.27 mm
ME+4/1	-0.53 mm	-0.19 mm
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ME-1/1	-1.54 mm	-0.27 mm
ME-1/2	+0.11 mm	+0.02 mm
ME-2/1	+0.04 mm	+0.01 mm
ME-2/2	-0.79 mm	-0.14 mm
ME-3/1	-0.11 mm	-0.04 mm
ME-3/2	-1.56 mm	-0.27 mm
ME-4/1	-0.55 mm	-0.19 mm

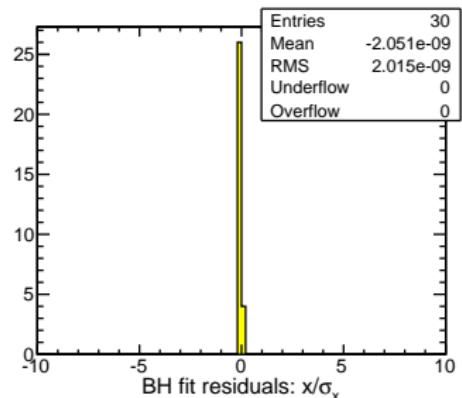
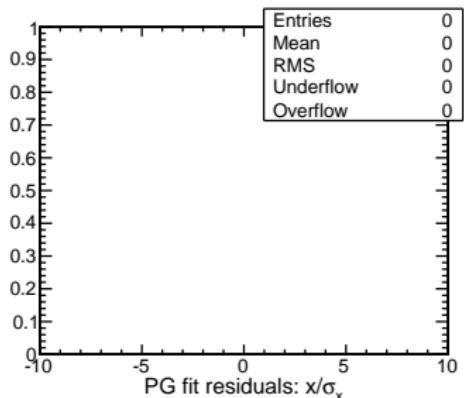
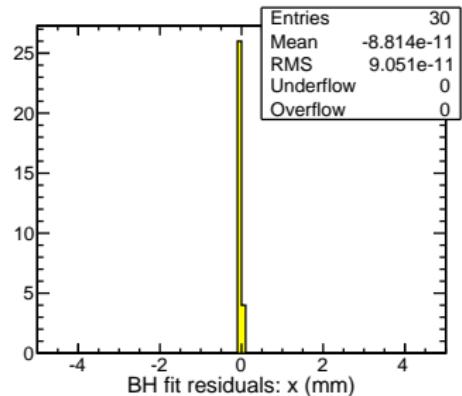
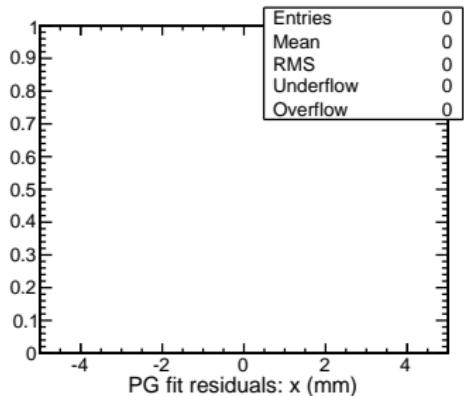
- ▶ Signs are “radius-after minus radius-before”
- ▶ The ME2/2, 3/2 rings get the largest additional correction

- ▶ Beam-halo alignment was applied to *disks*, rather than rings, so that the globalMuon alignment can combine statistics
 - ▶ cosmic ray globalMuons are much more precise for outer rings than inner rings
- ▶ There were nine separate fits:
 - ME+1/1: beam-halo only, disconnected segments between missing data
 - ME-1/1: same
 - YE+1: ME+1/2 and ME+1/3, PG in both, beam-halo only in ME+1/2
 - YE-1: same
 - YE+2: stations 2 and 2, PG in both, beam-halo in both
 - YE-2: same
 - ME+4/1: PG and beam-halo
 - ME-4/1: same
 - ME+4/2: beam-halo only alignment of 5 chambers
- ▶ Aligned in 6 iterations: (1) $r\phi$, (2) ϕ_z , (3) $r\phi$, (4) ϕ_z , (5) $r\phi$, (6) ϕ_z

Convergence in $r\phi$ positions

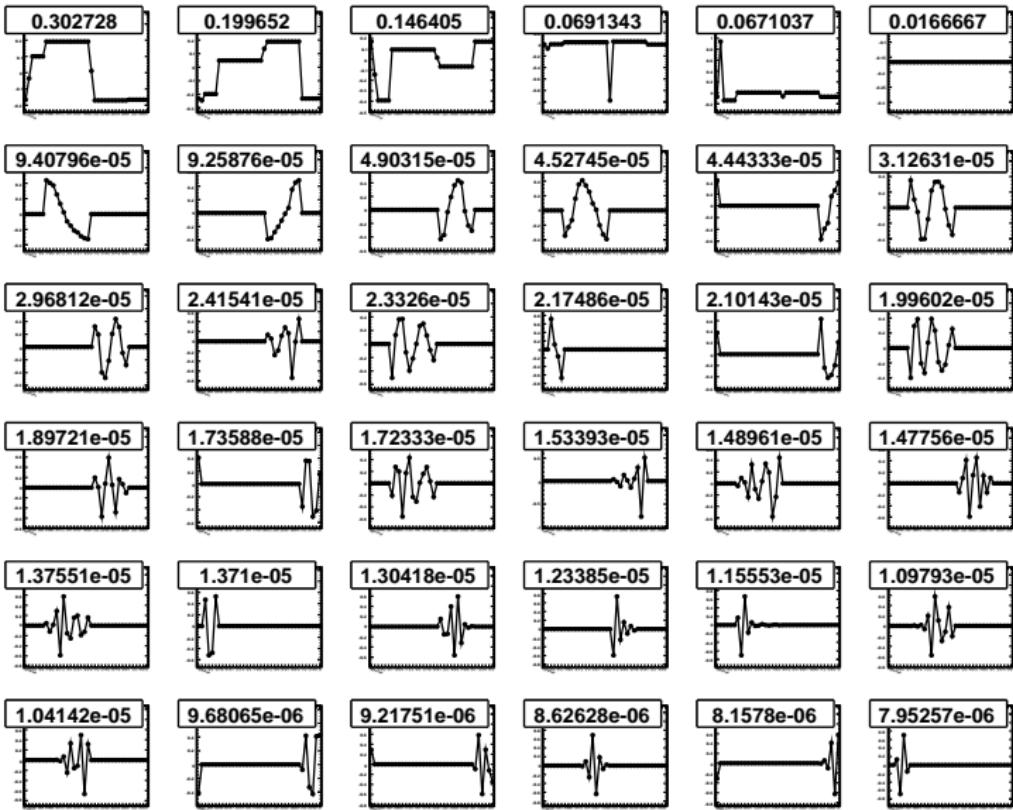


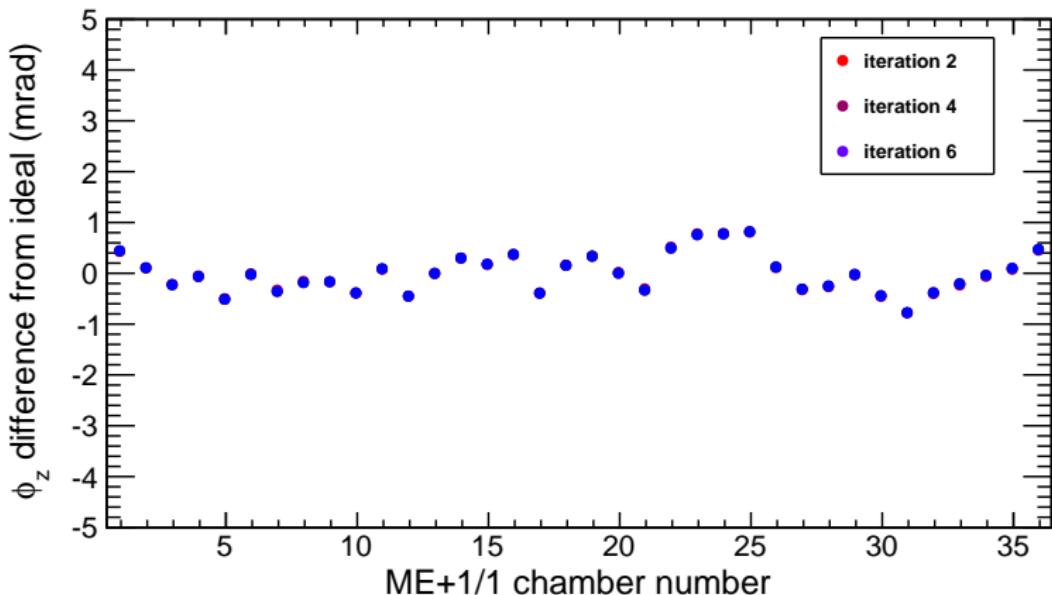
Fit residuals in $r\phi$ (not track residuals): no PG, perfect BH fit





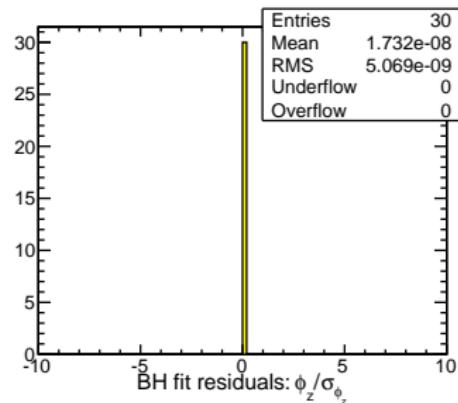
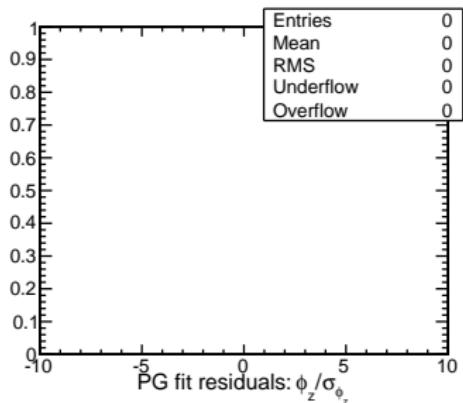
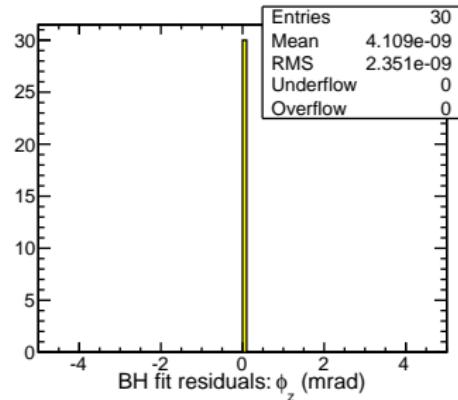
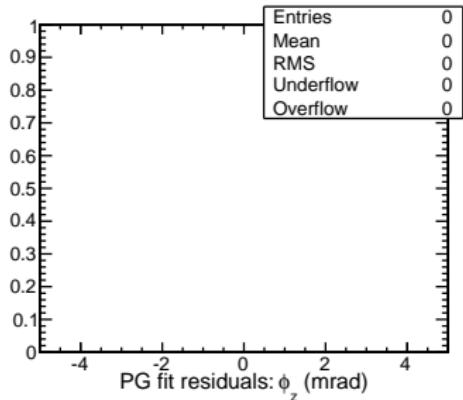
Numbers in boxes are ϕ position uncertainty in each mode in rad
First 6 are completely undetermined (uncertainty is meaningless)



Convergence in ϕ_z angles

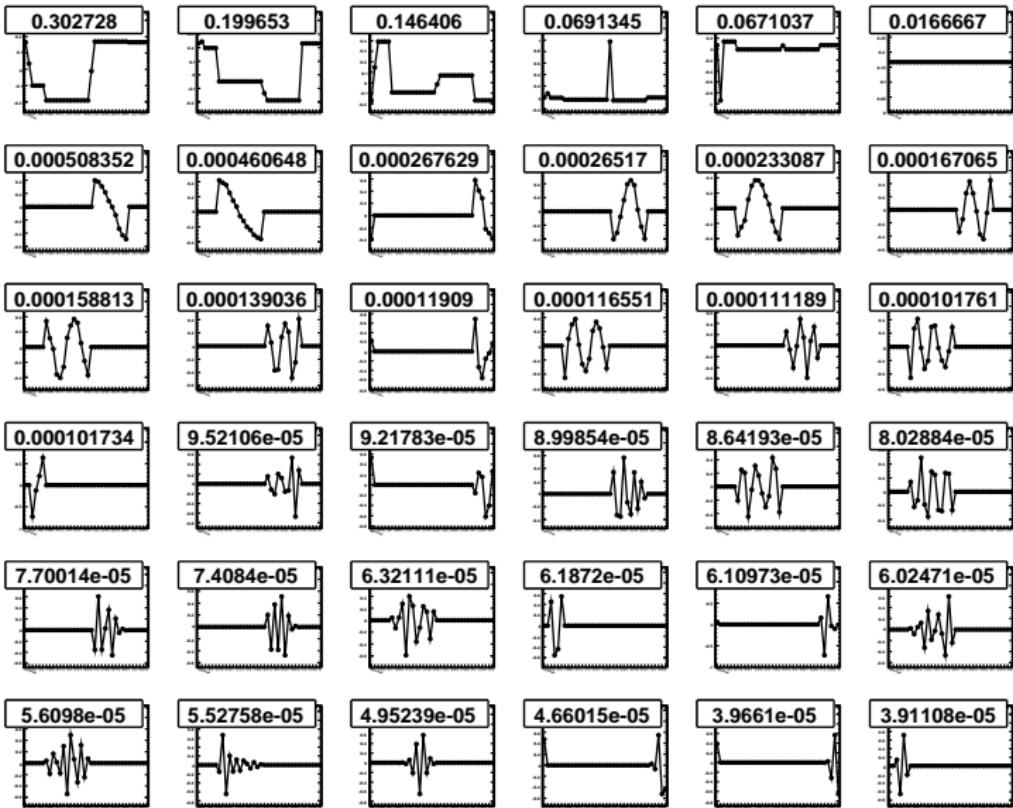


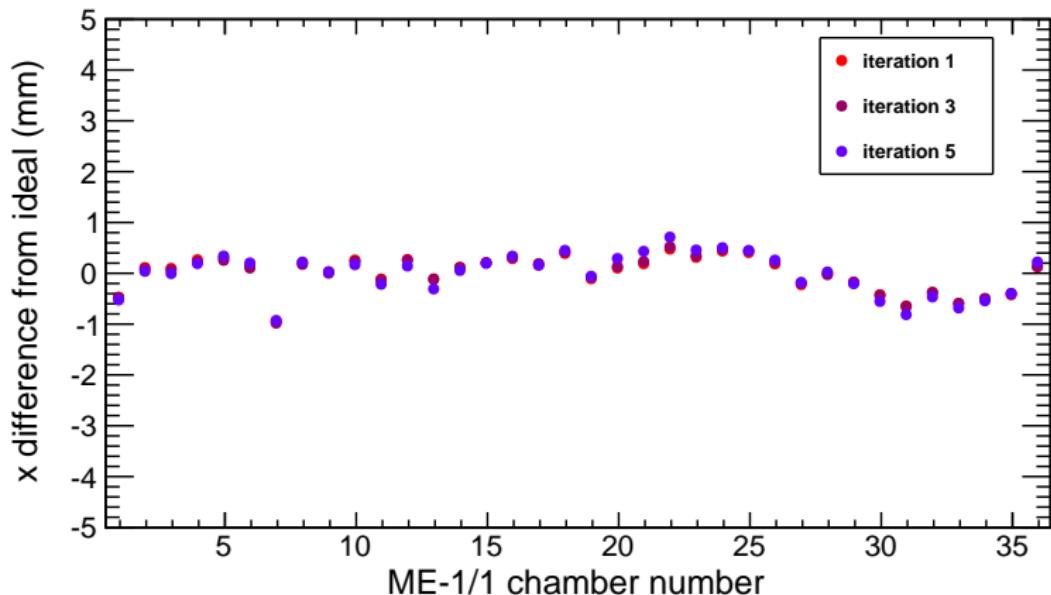
Fit residuals in ϕ_z (not track residuals): no PG, perfect BH fit





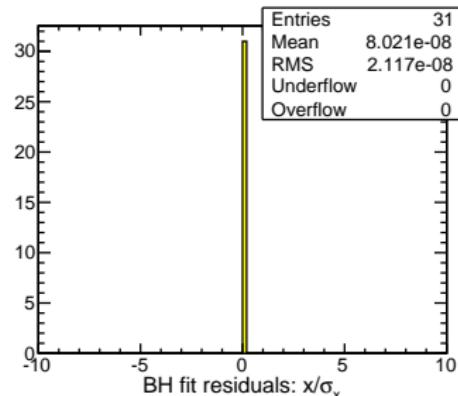
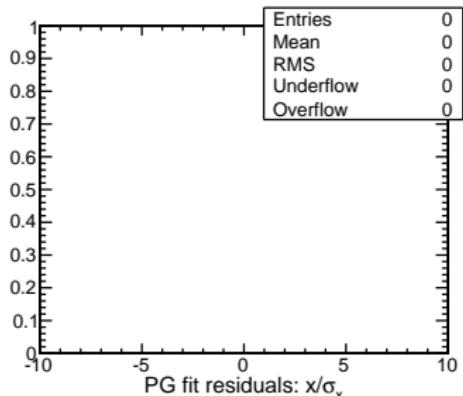
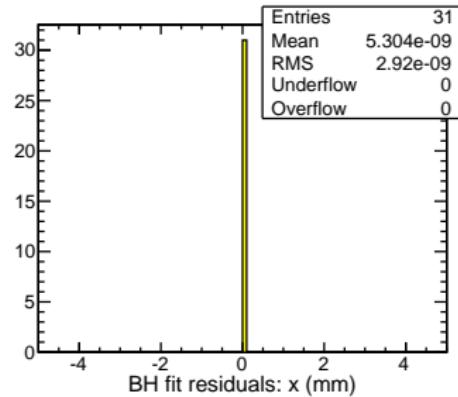
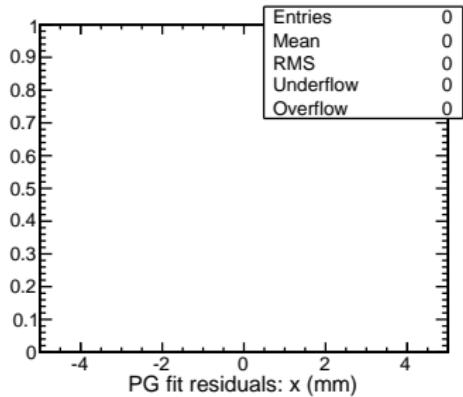
Numbers in boxes are ϕ_z angle uncertainty in each mode in rad
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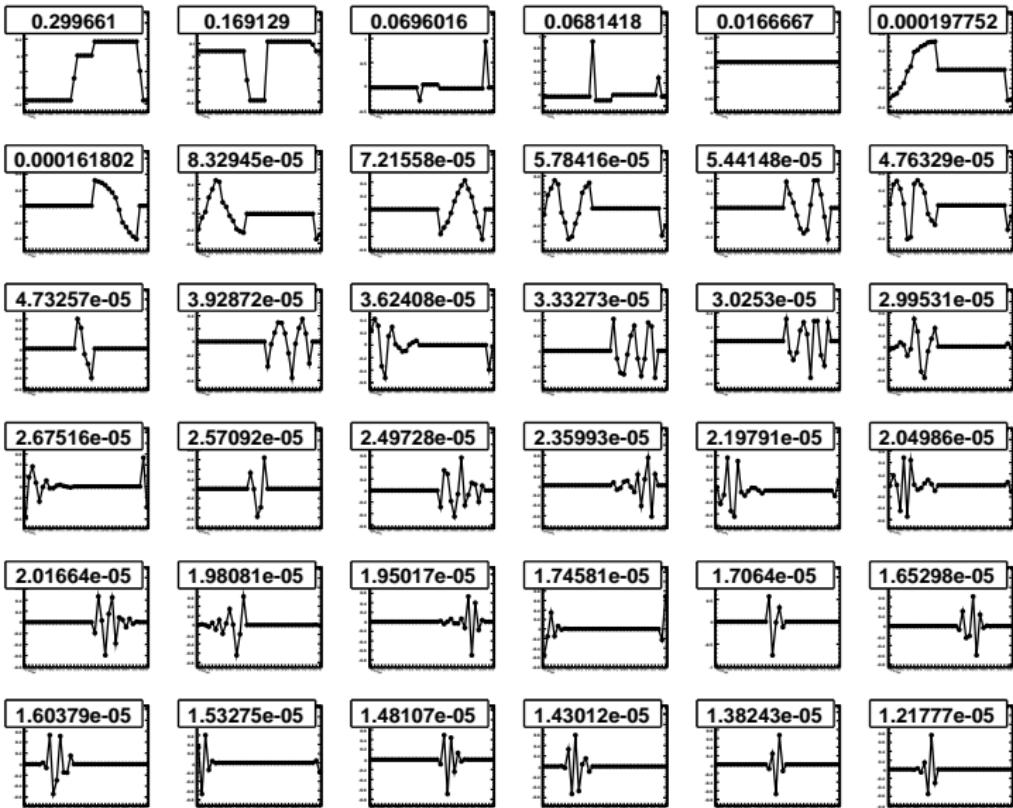
Convergence in $r\phi$ positions

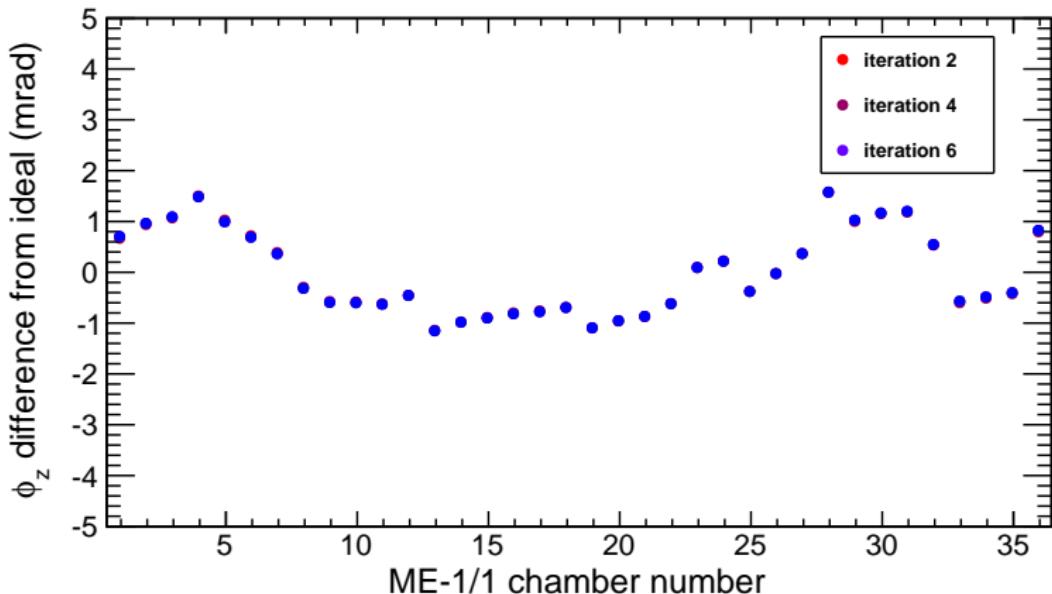


Fit residuals in $r\phi$ (not track residuals): no PG, perfect BH fit



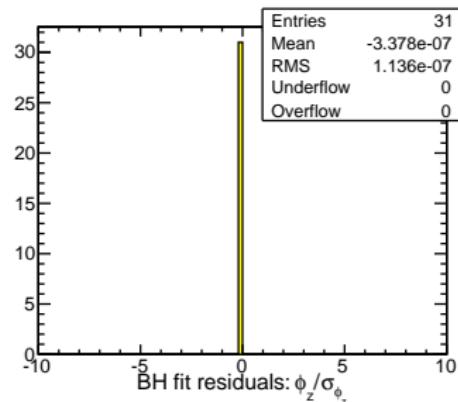
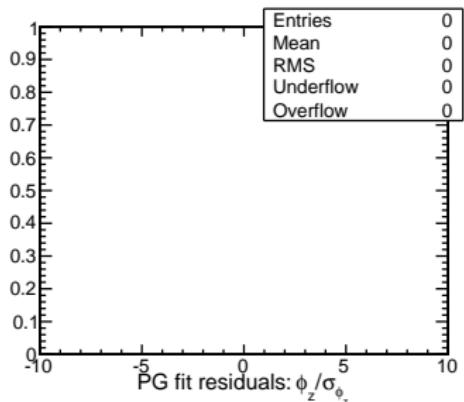
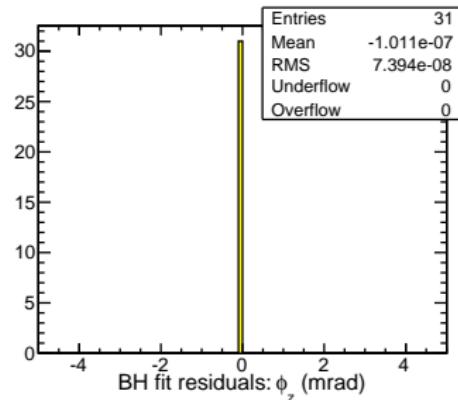
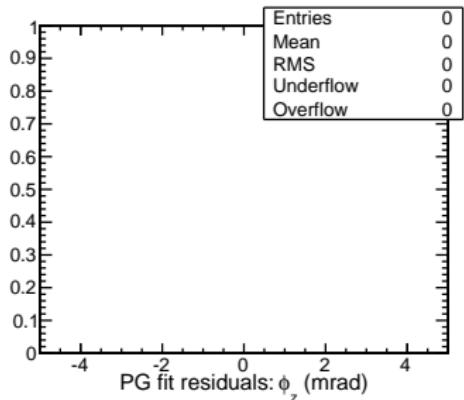
Numbers in boxes are ϕ position uncertainty in each mode in rad
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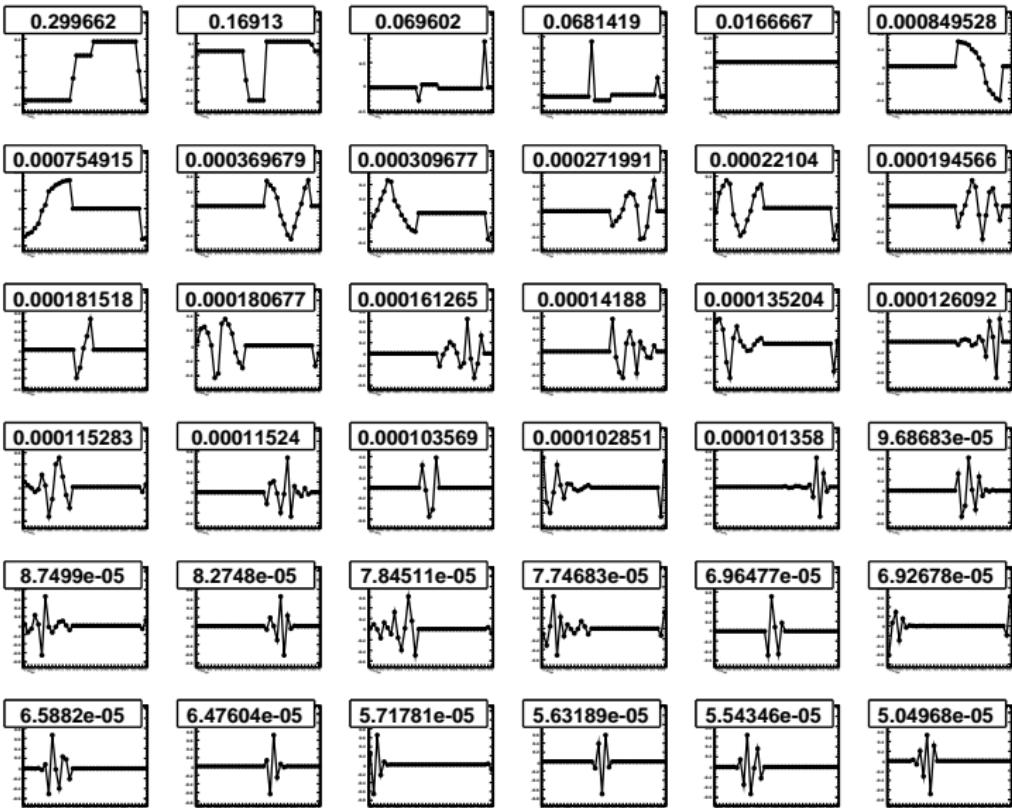
Convergence in ϕ_z angles

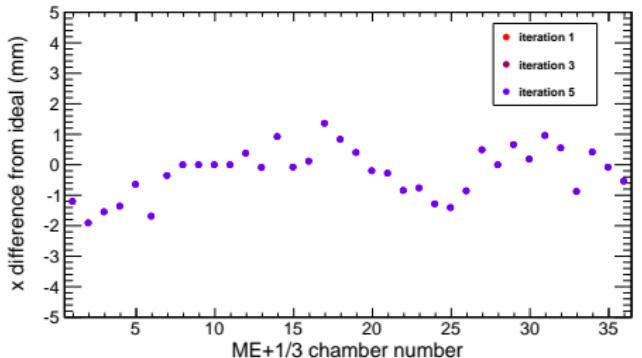
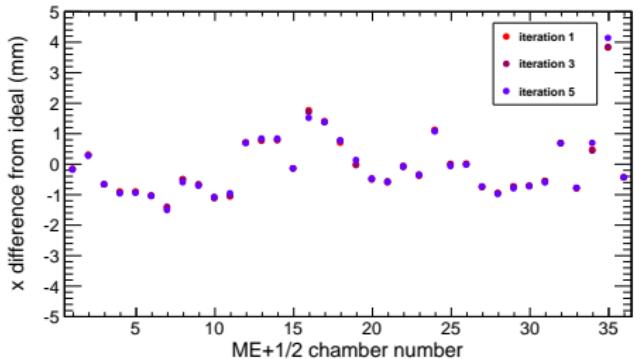


Fit residuals in ϕ_z (not track residuals): no PG, perfect BH fit



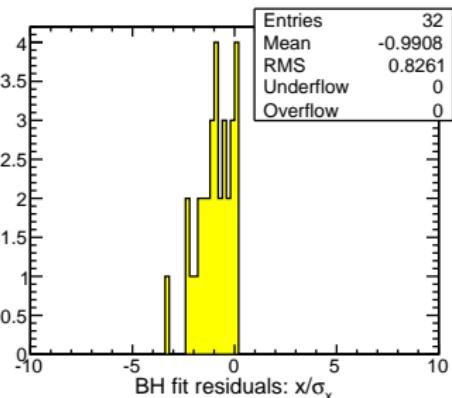
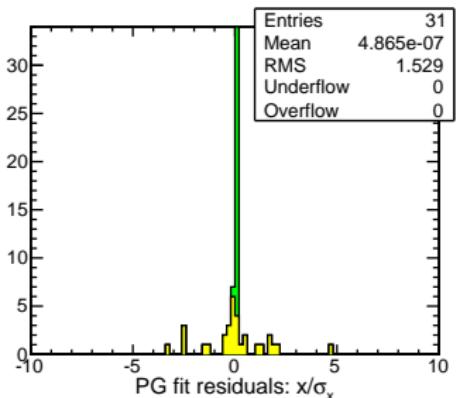
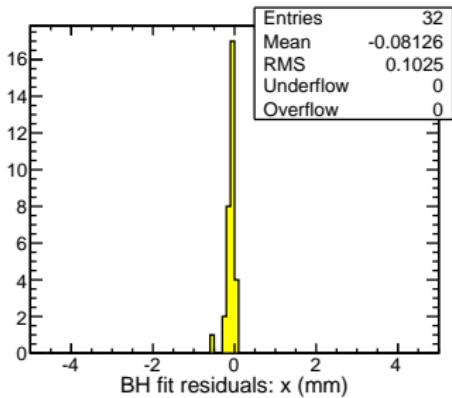
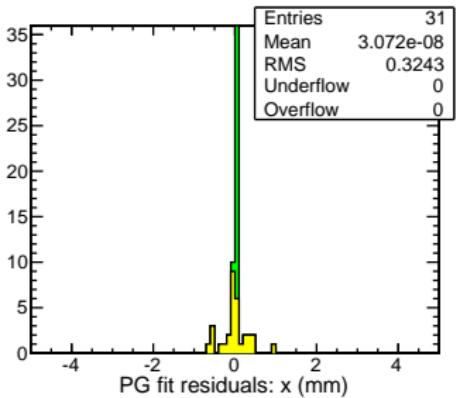
Numbers in boxes are ϕ_z angle uncertainty in each mode in rad
First 7 are completely undetermined (uncertainty is meaningless)



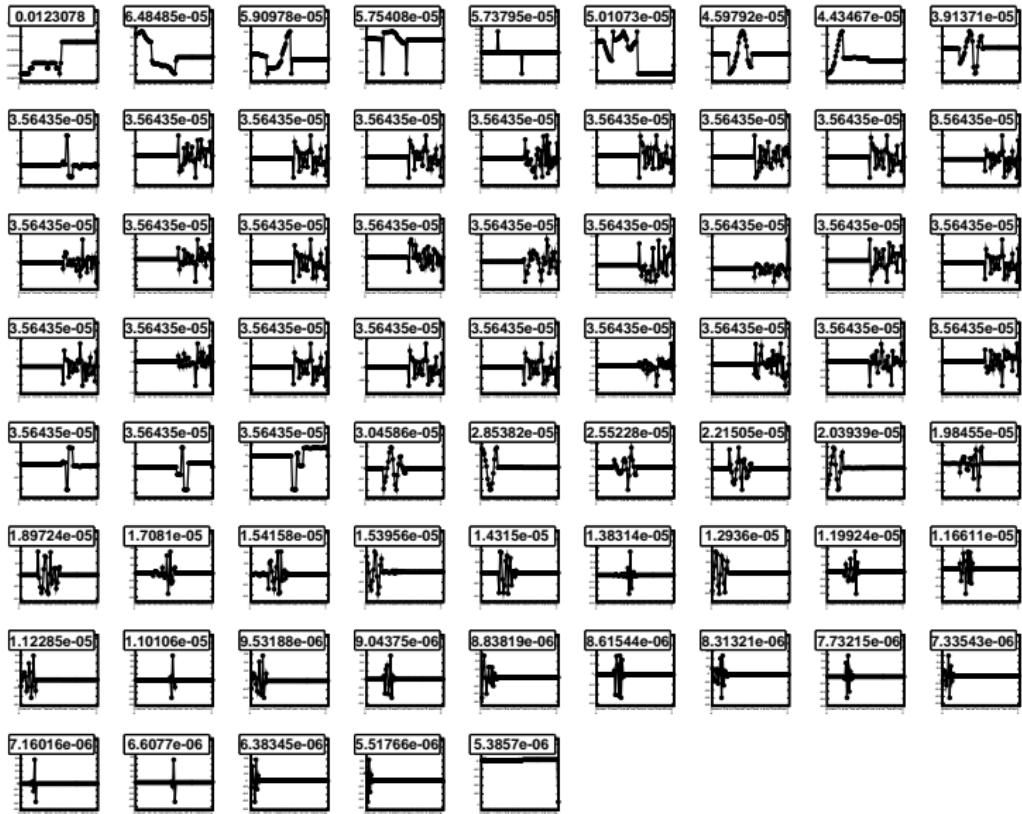
Convergence in $r\phi$ positions

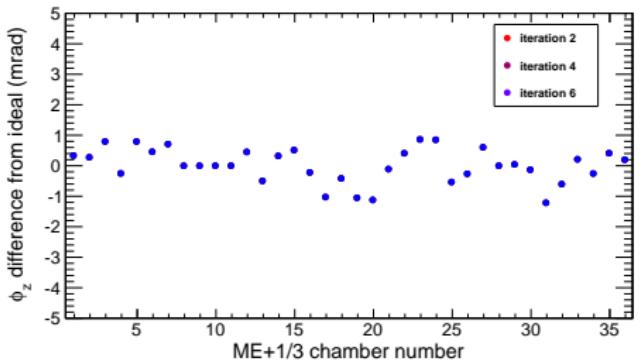
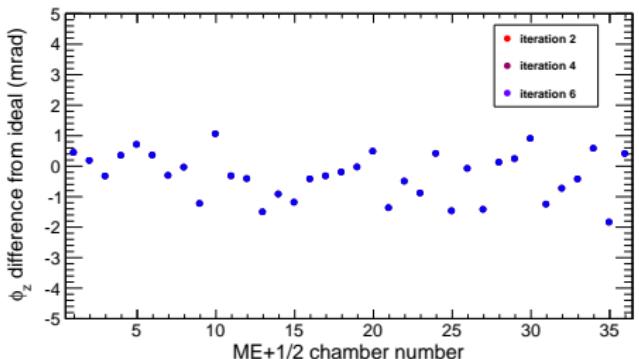


Fit residuals in $r\phi$ (not track residuals): no BH in ME+1/3 (green)



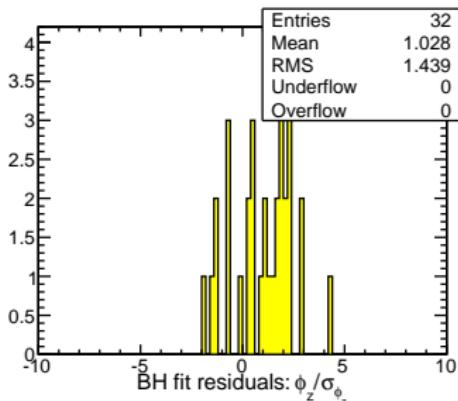
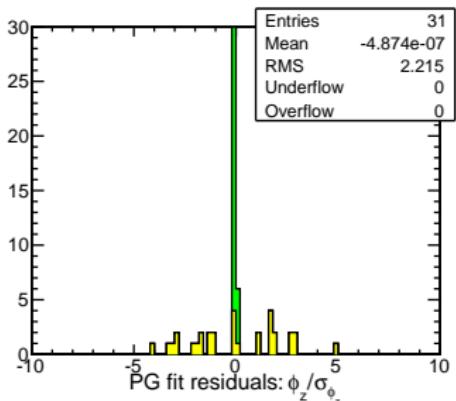
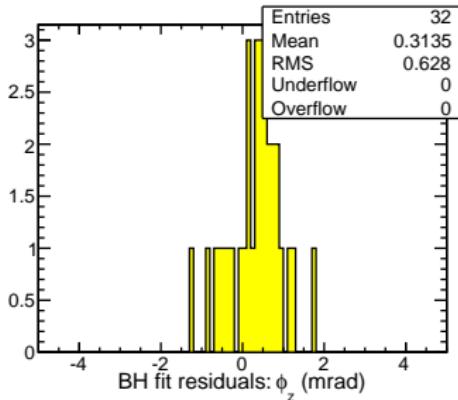
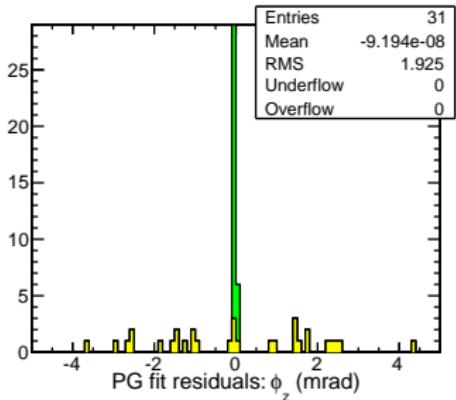
Numbers in boxes are ϕ position uncertainty in each mode in rad
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Convergence in ϕ_z positions

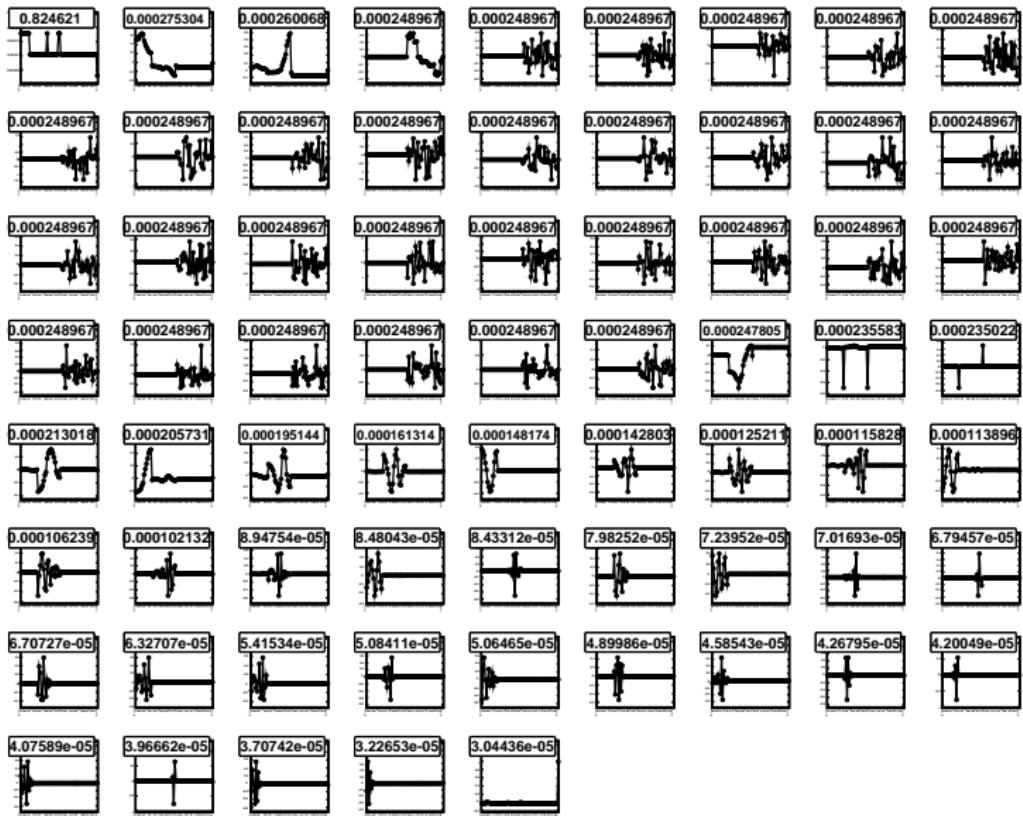


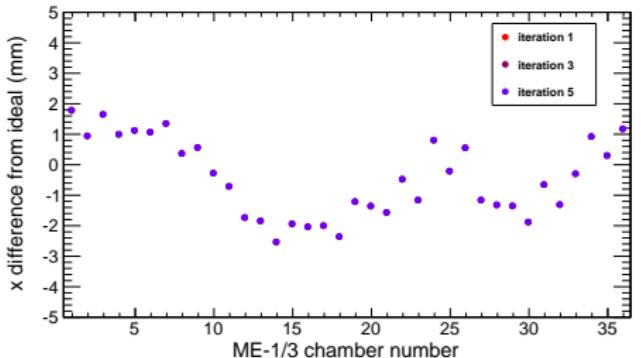
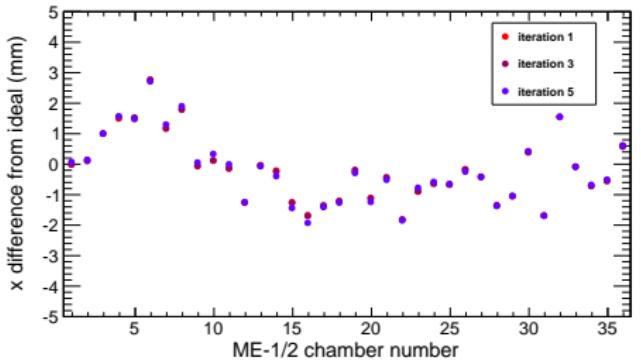
Fit residuals in ϕ_z (not track residuals): no BH in ME+1/3 (green)





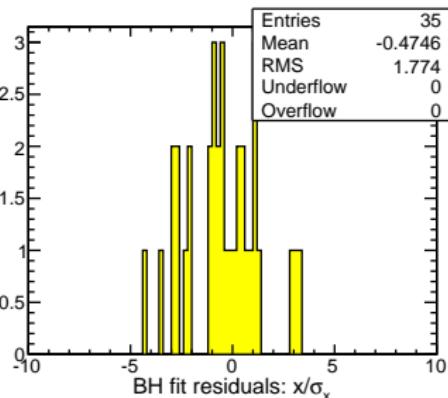
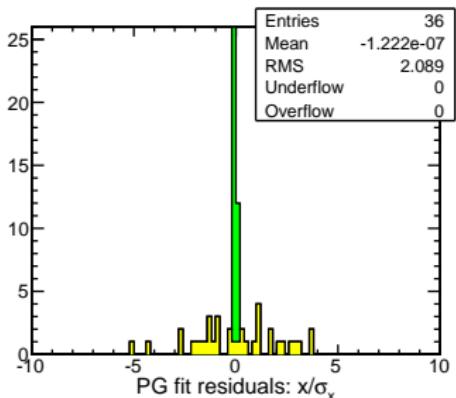
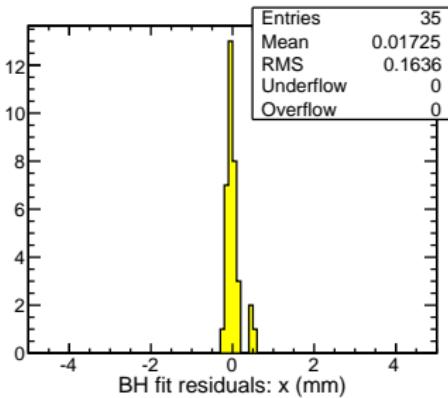
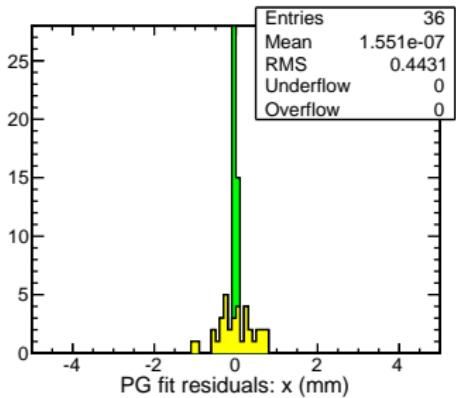
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Convergence in $r\phi$ positions

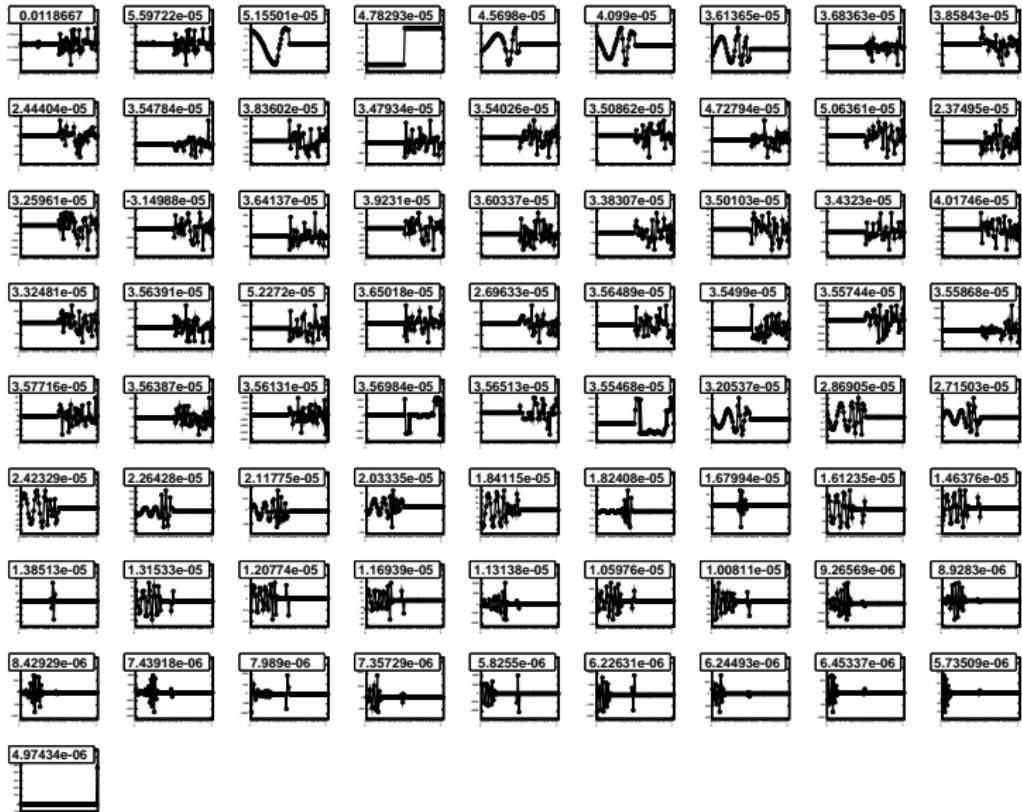


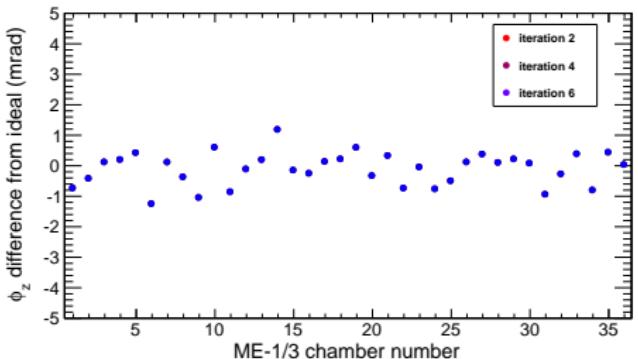
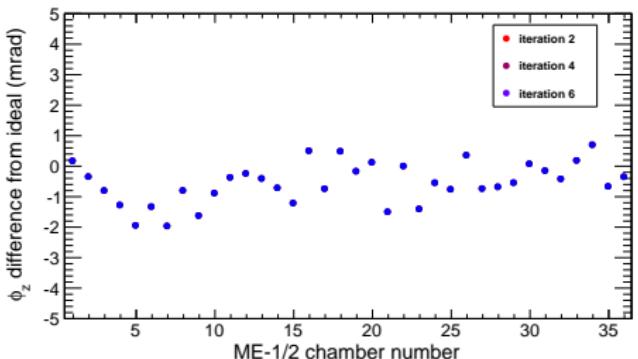
Fit residuals in $r\phi$ (not track residuals): no BH in ME-1/3 (green)





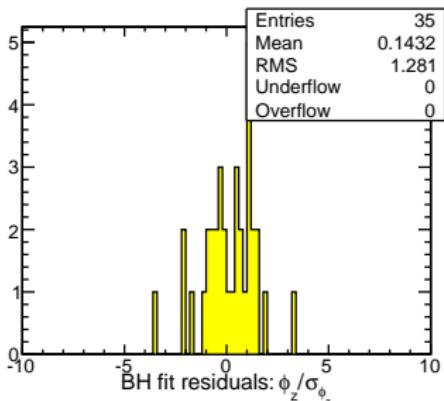
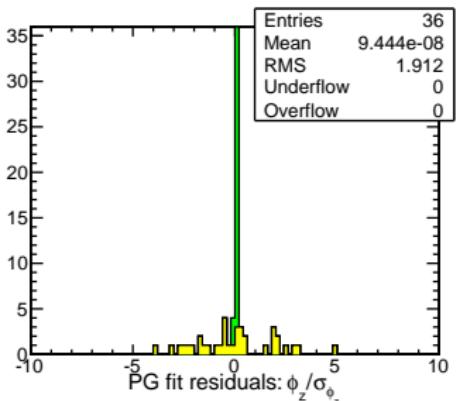
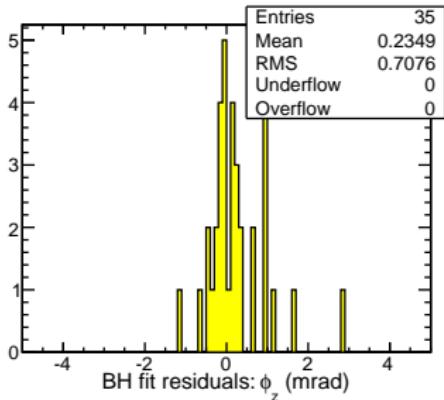
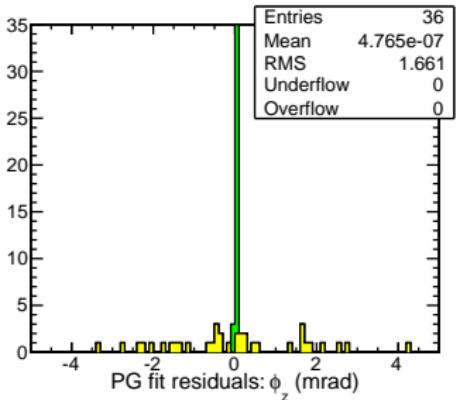
Numbers in boxes are ϕ position uncertainty in each mode in rad
First 1 is completely undetermined (uncertainty is meaningless)



Convergence in ϕ_z positions



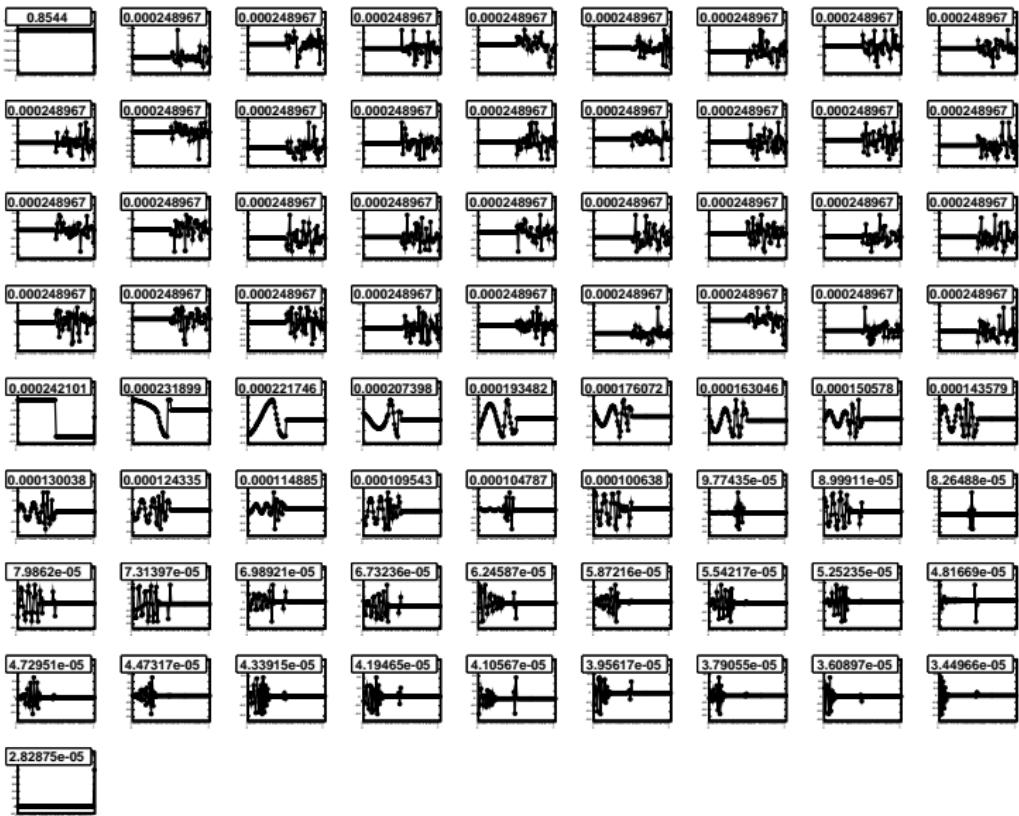
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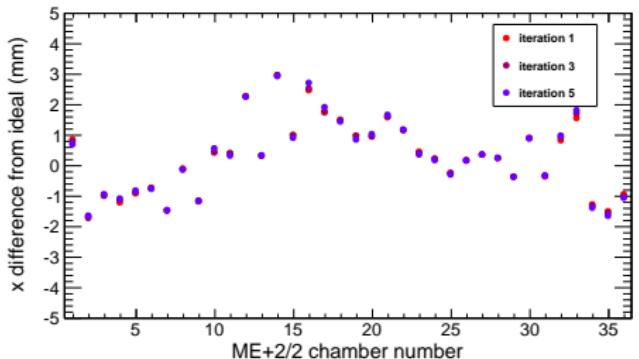
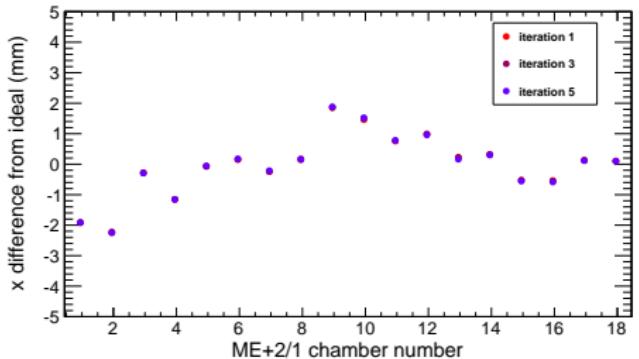


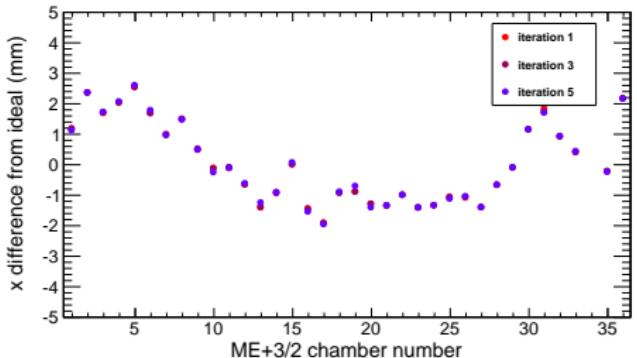
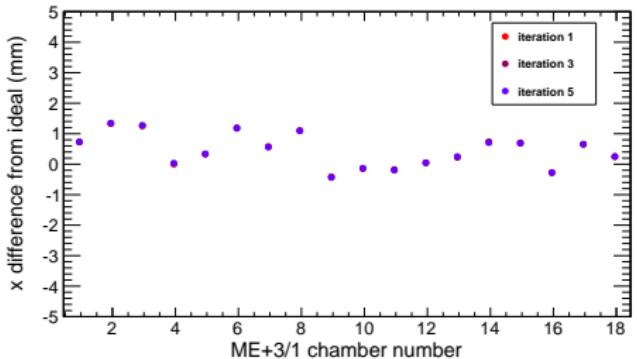
$$YE^{-1} \phi_z$$

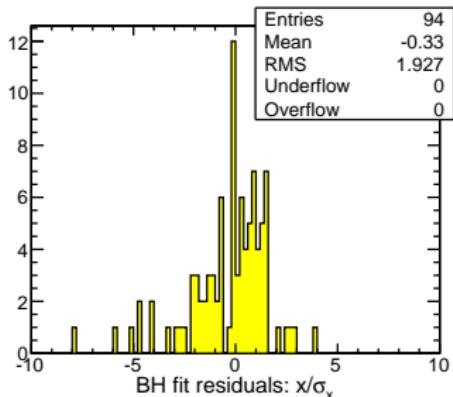
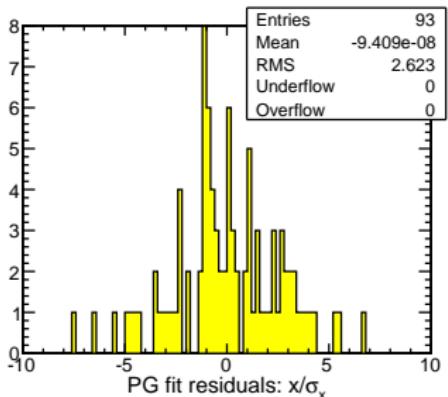
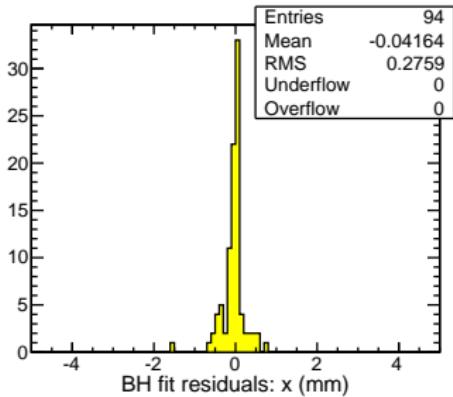
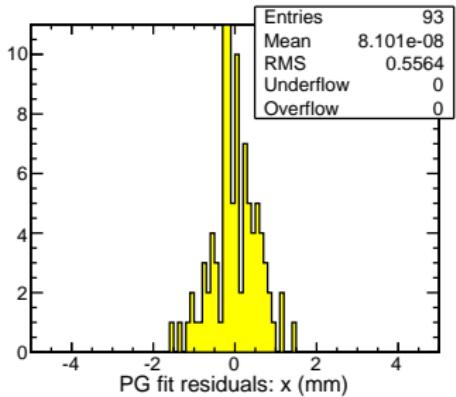


Numbers in boxes are ϕ_z angle uncertainty in each mode in rad
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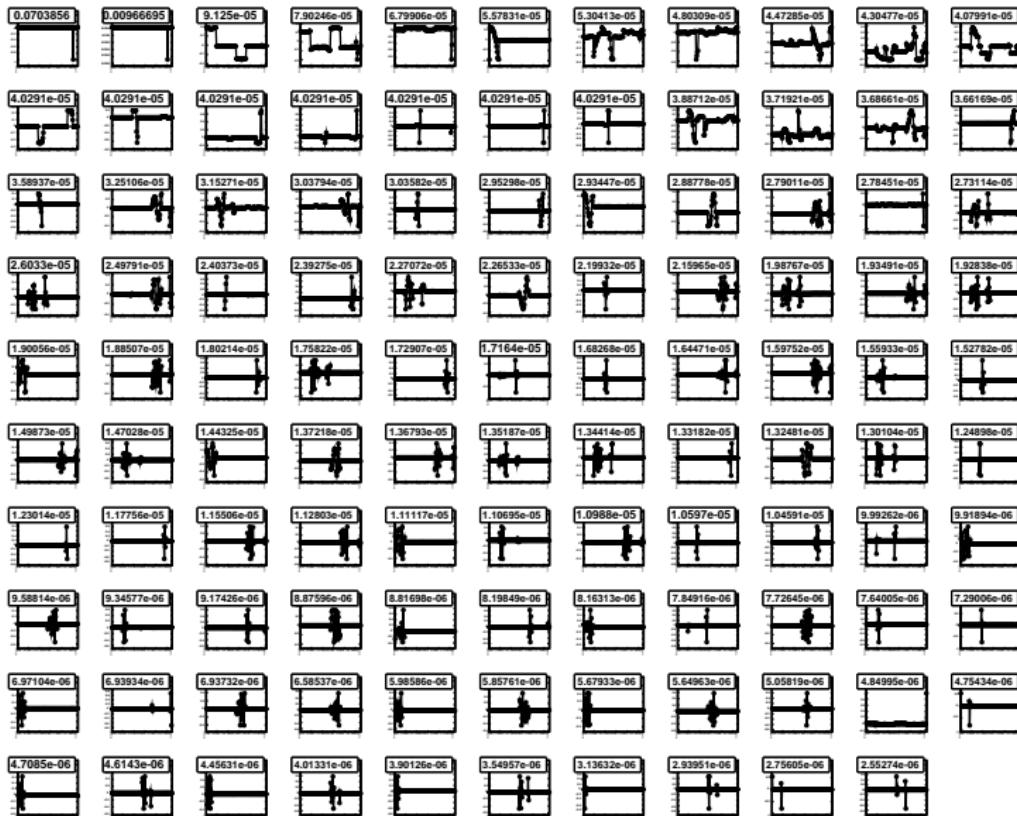
Convergence in $r\phi$ positions

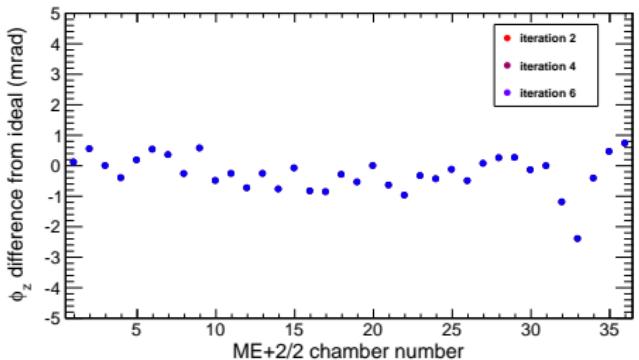
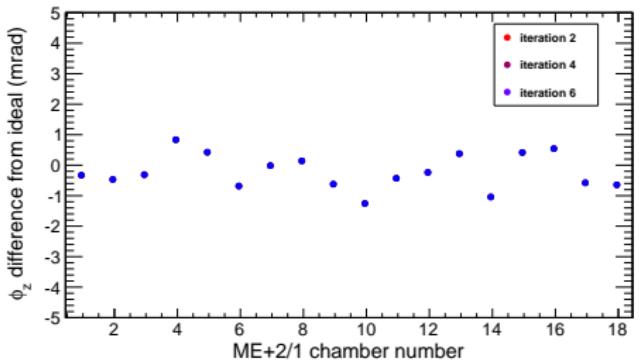
Convergence in $r\phi$ positions

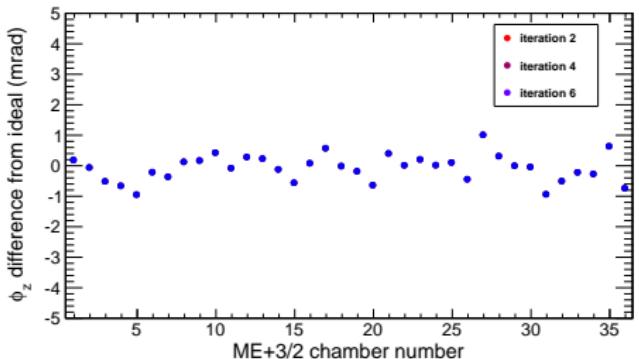
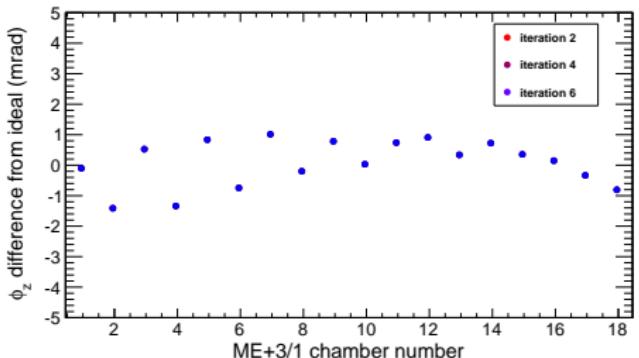
Fit residuals in $r\phi$ (not track residuals)

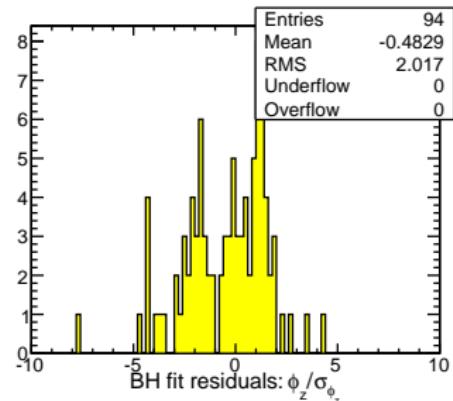
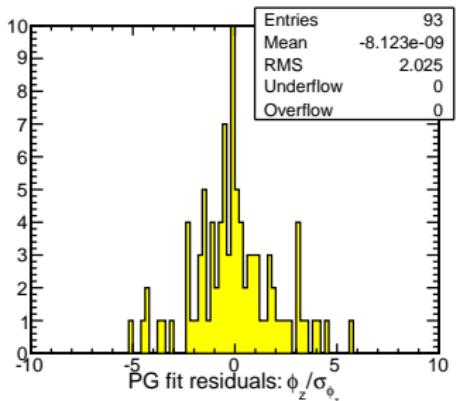
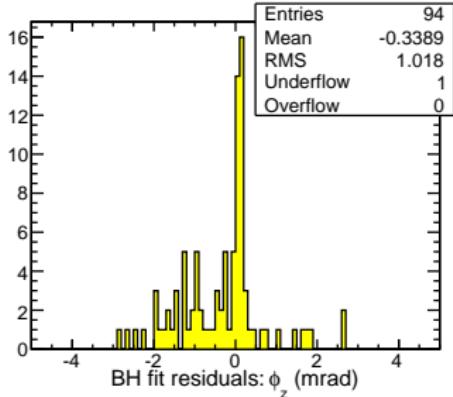
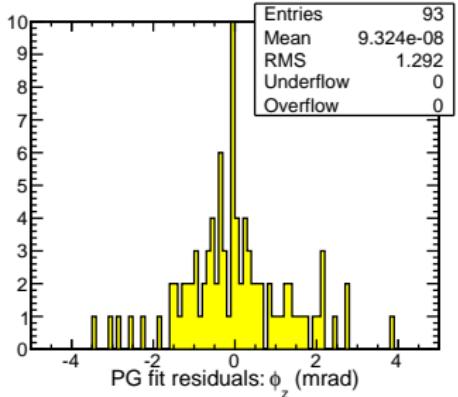


Numbers in boxes are ϕ position uncertainty in each mode in rad
First 2 are completely undetermined (uncertainty is meaningless)

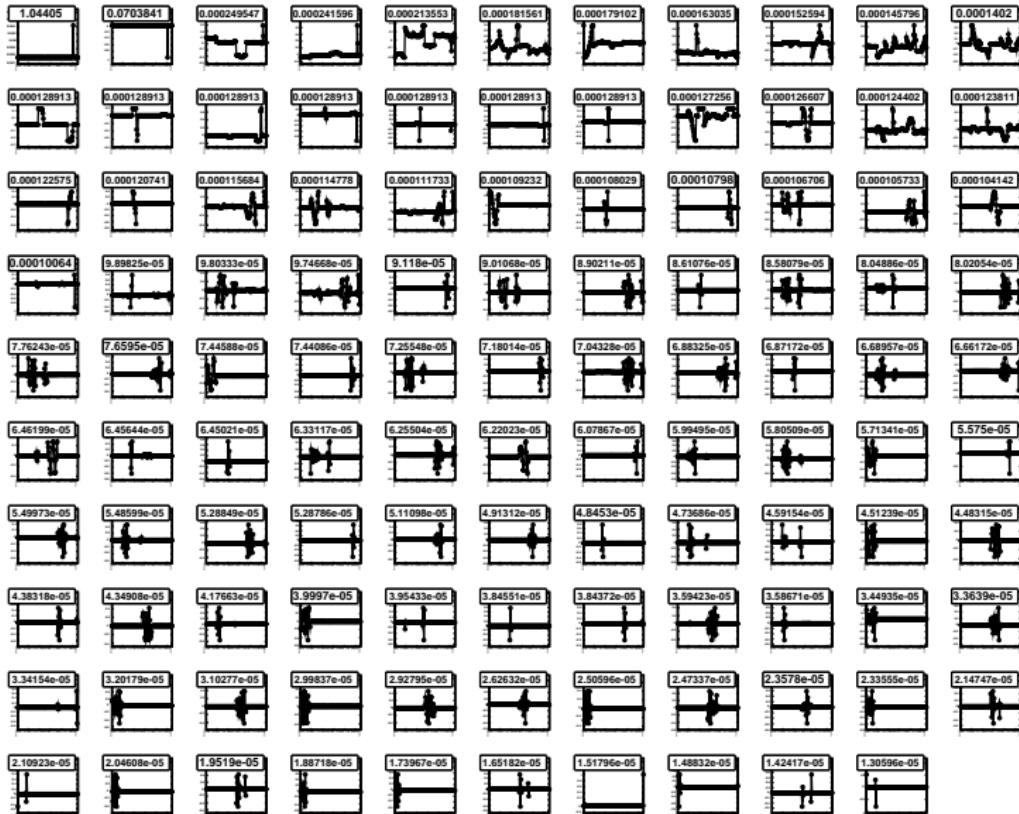


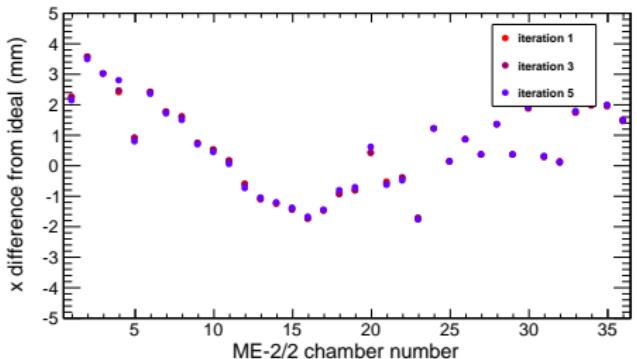
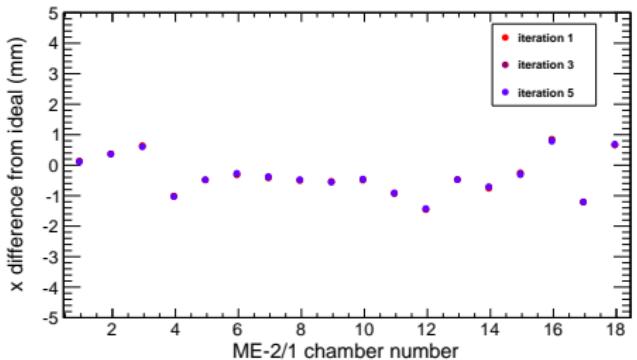
Convergence in ϕ_z positions

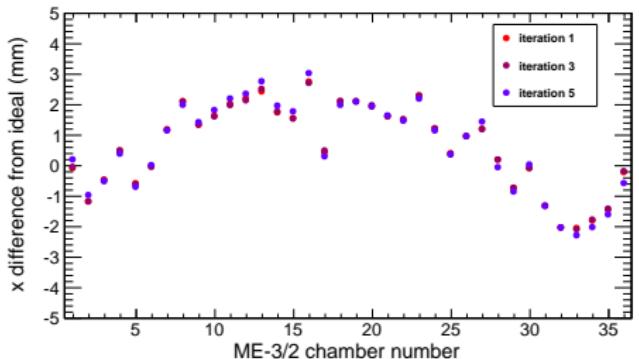
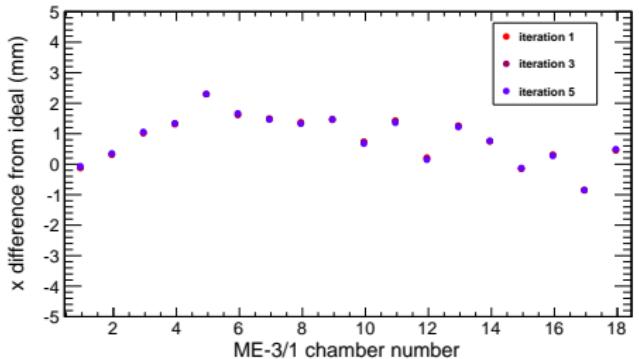
Convergence in ϕ_z positions

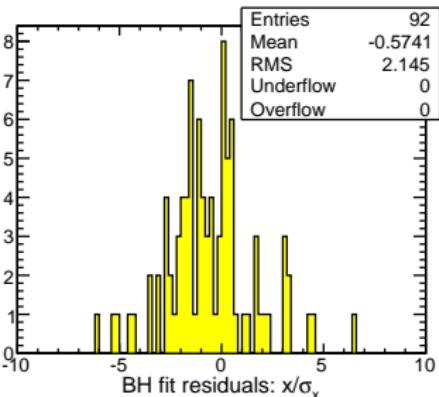
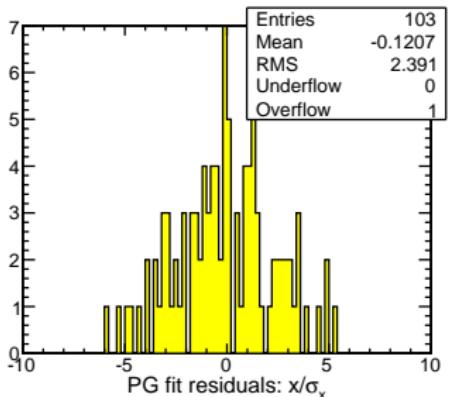
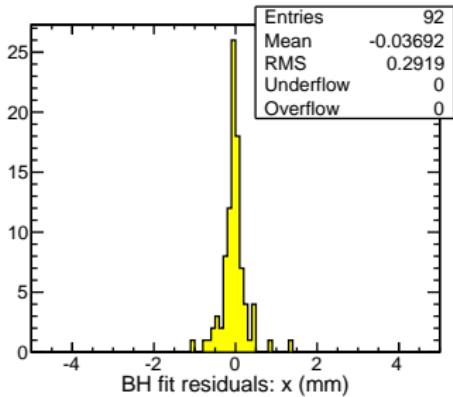
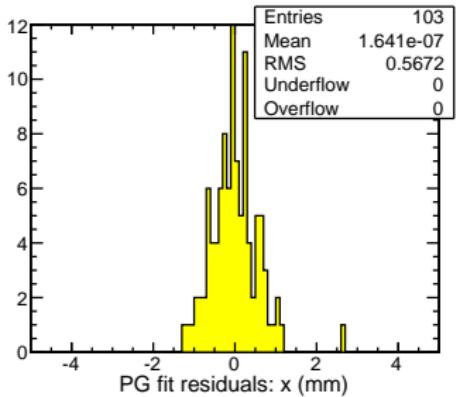
Fit residuals in ϕ_z (not track residuals)

Numbers in boxes are ϕ_z angle uncertainty in each mode in rad
 First 2 are completely undetermined (uncertainty is meaningless)

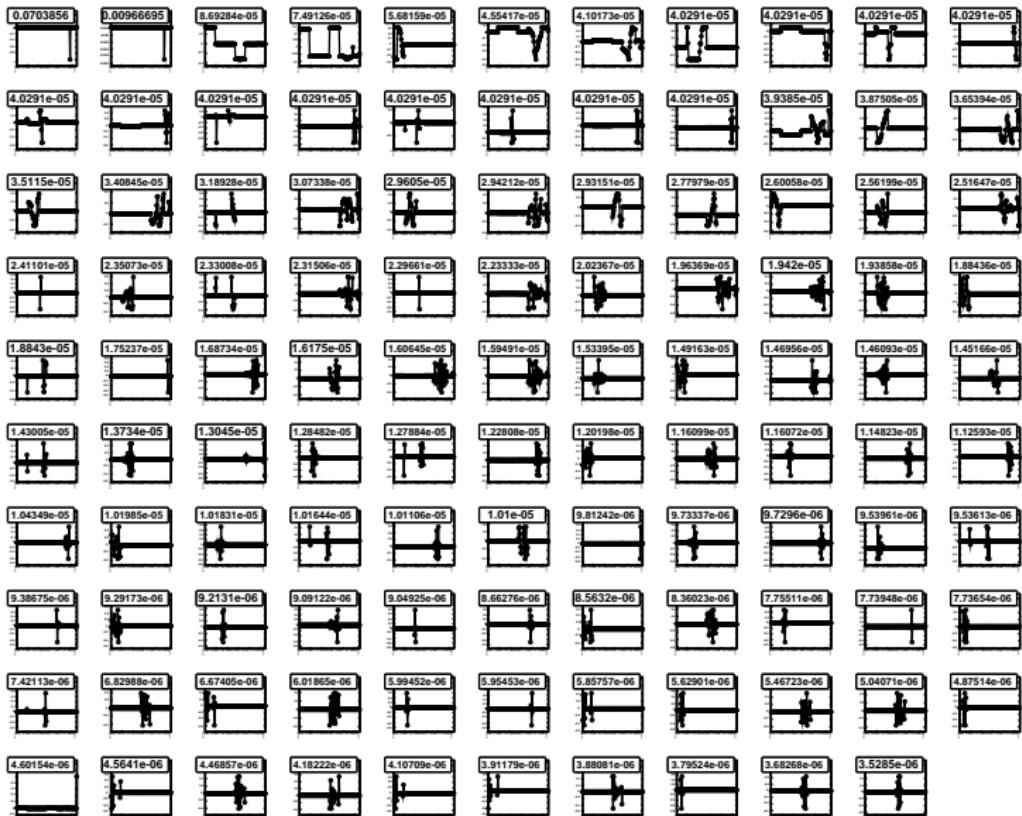


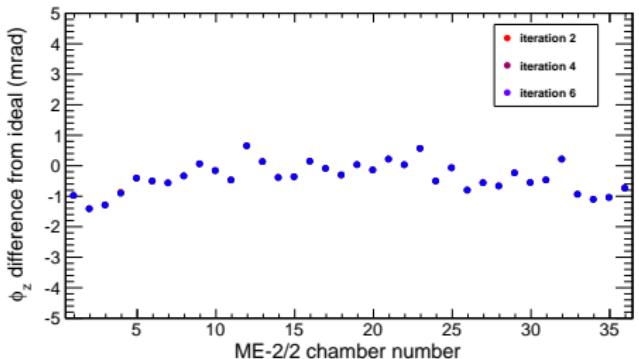
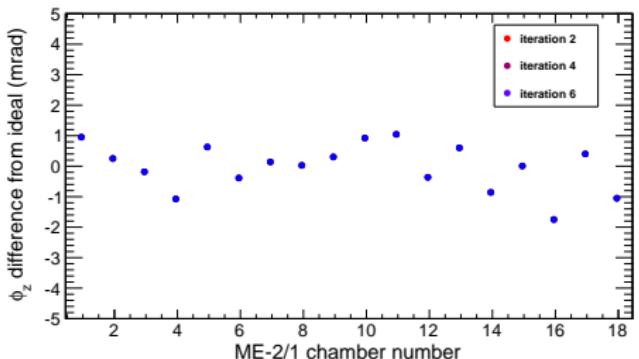
Convergence in $r\phi$ positions

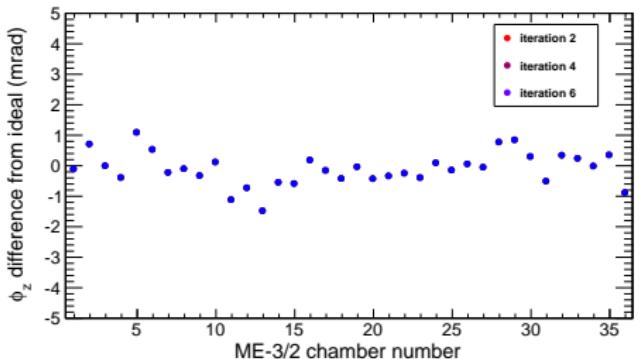
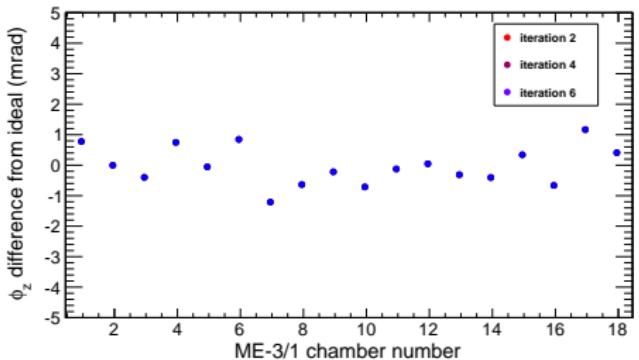
Convergence in $r\phi$ positions

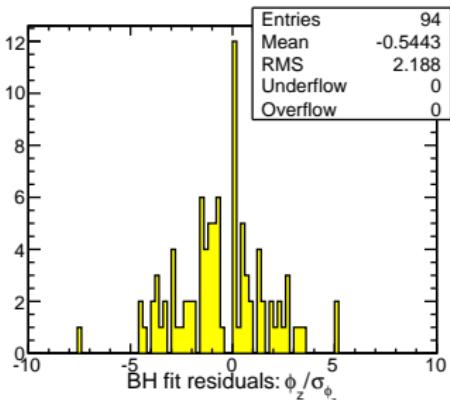
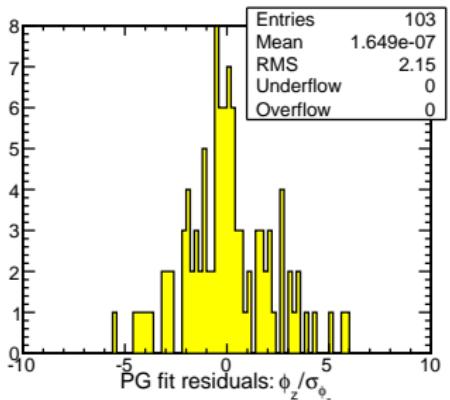
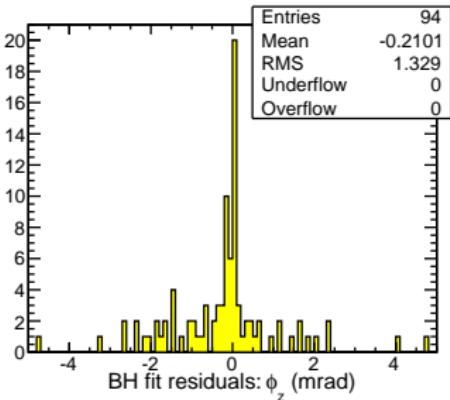
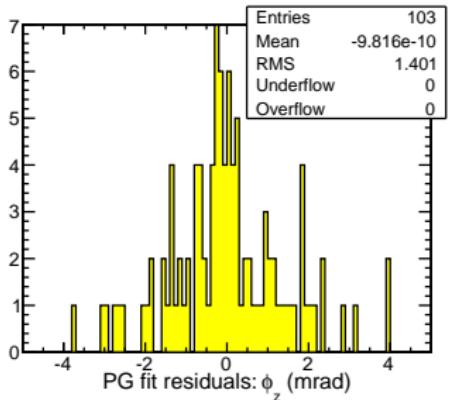
Fit residuals in $r\phi$ (not track residuals)

Numbers in boxes are ϕ position uncertainty in each mode in rad
First 2 are completely undetermined (uncertainty is meaningless)

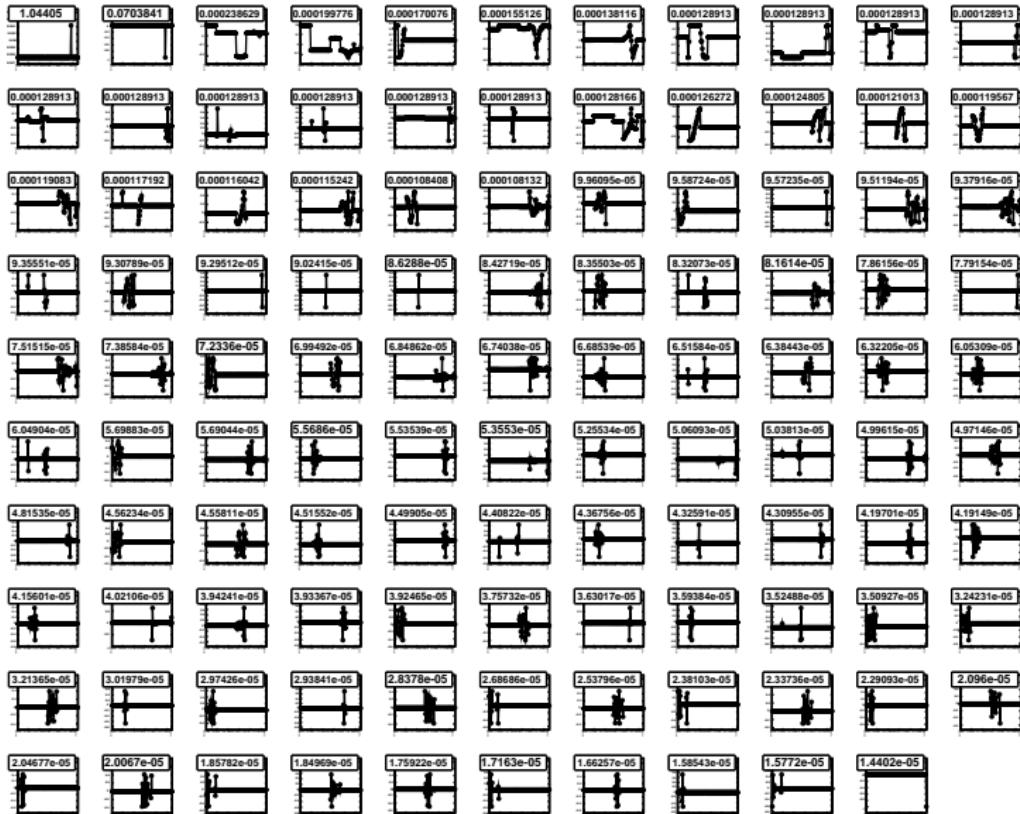


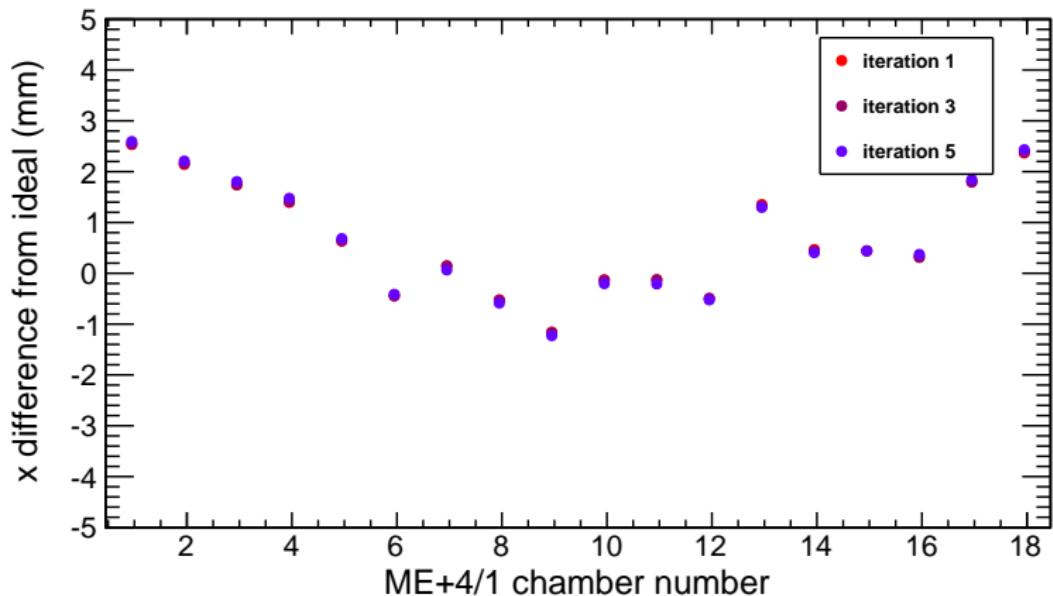
Convergence in ϕ_z positions

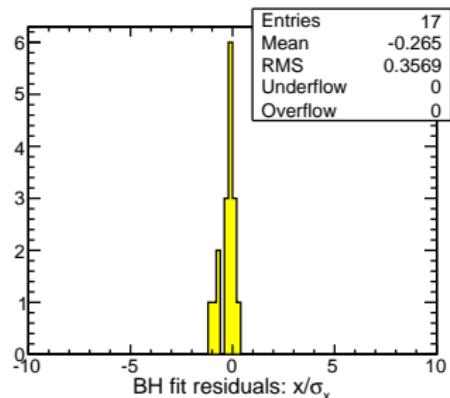
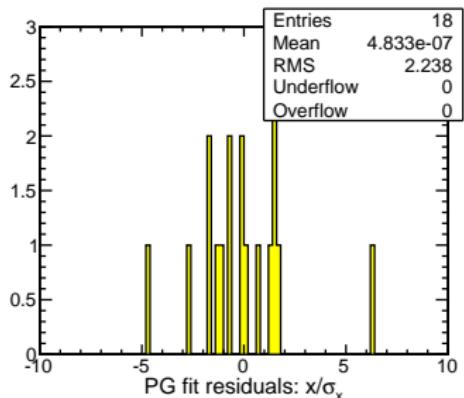
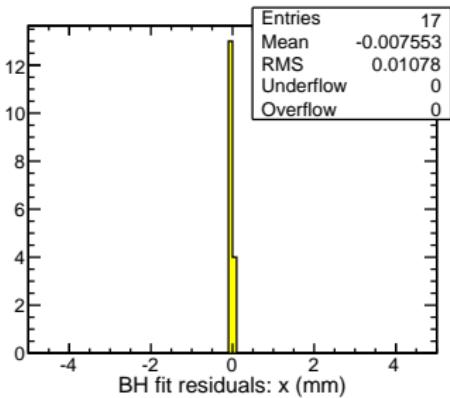
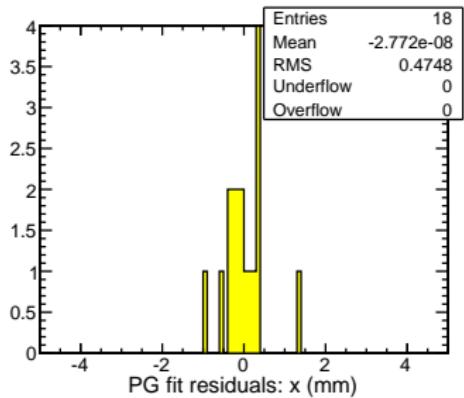
Convergence in ϕ_z positions

Fit residuals in ϕ_z (not track residuals)

Numbers in boxes are ϕ_z angle uncertainty in each mode in rad
 First 2 are completely undetermined (uncertainty is meaningless)

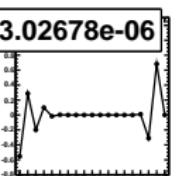
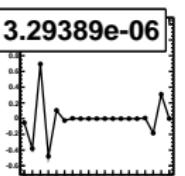
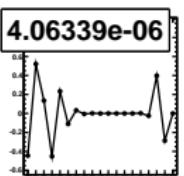
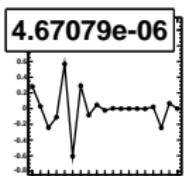
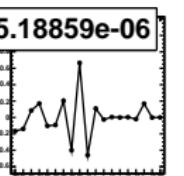
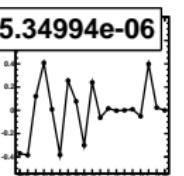
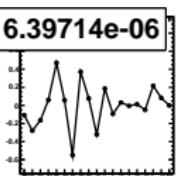
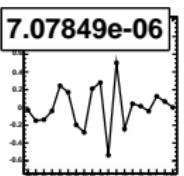
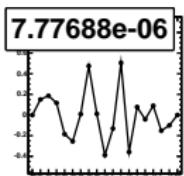
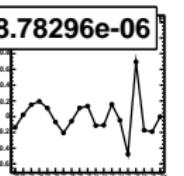
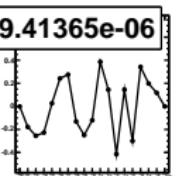
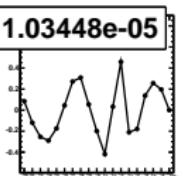
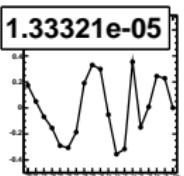
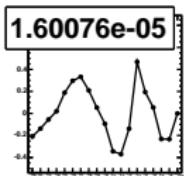
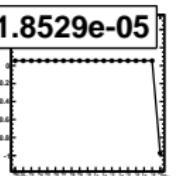
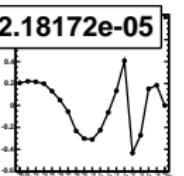
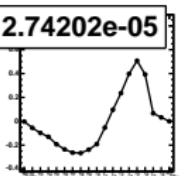
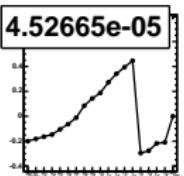
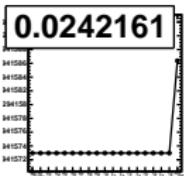


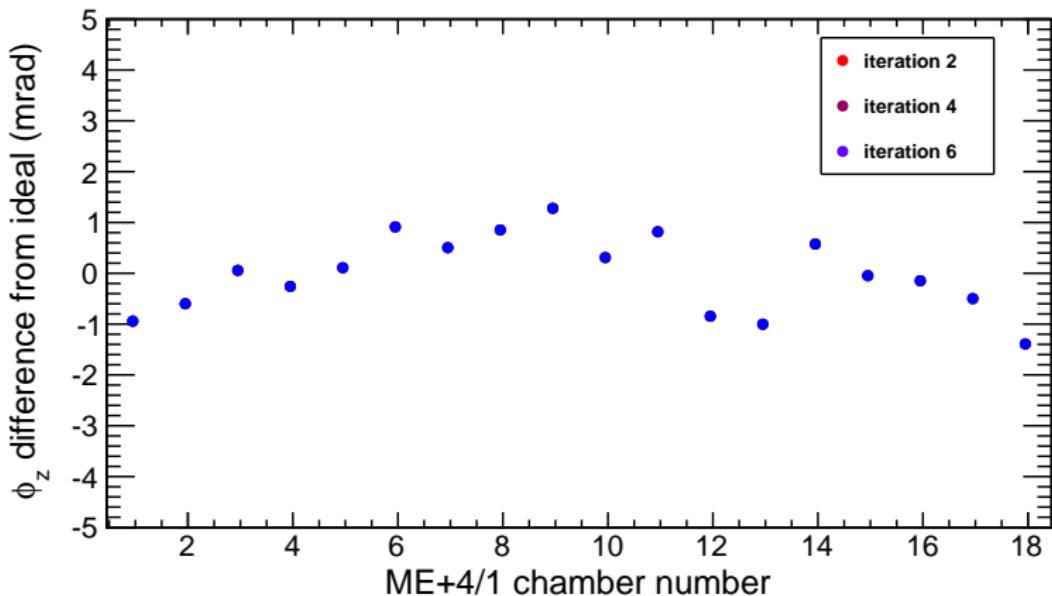
Convergence in $r\phi$ positions

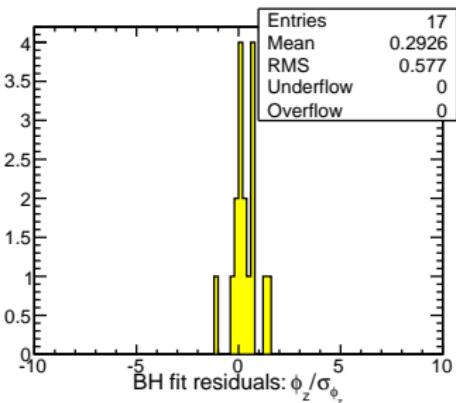
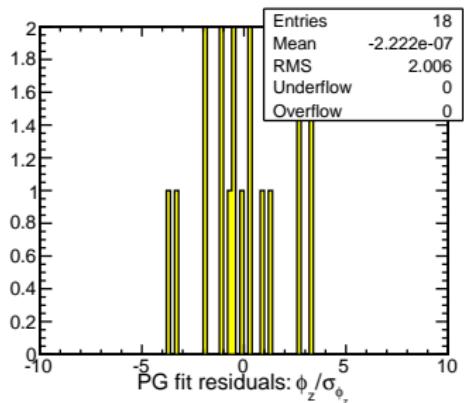
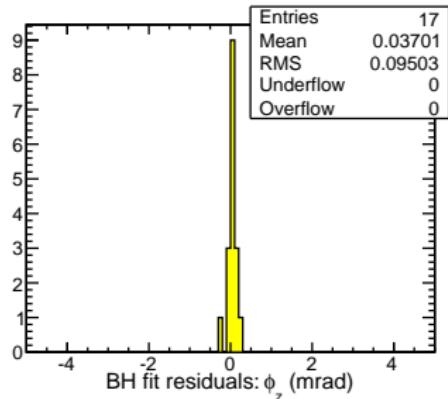
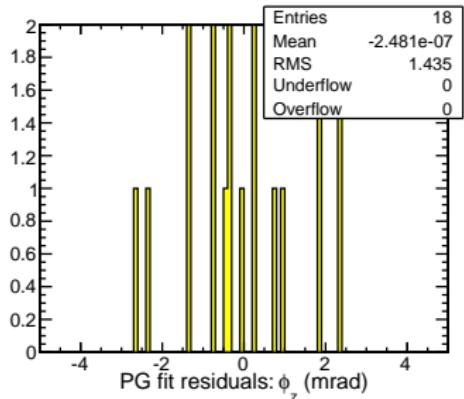
Fit residuals in $r\phi$ (not track residuals)



Numbers in boxes are ϕ position uncertainty in each mode in rad
First 1 is completely undetermined (uncertainty is meaningless)

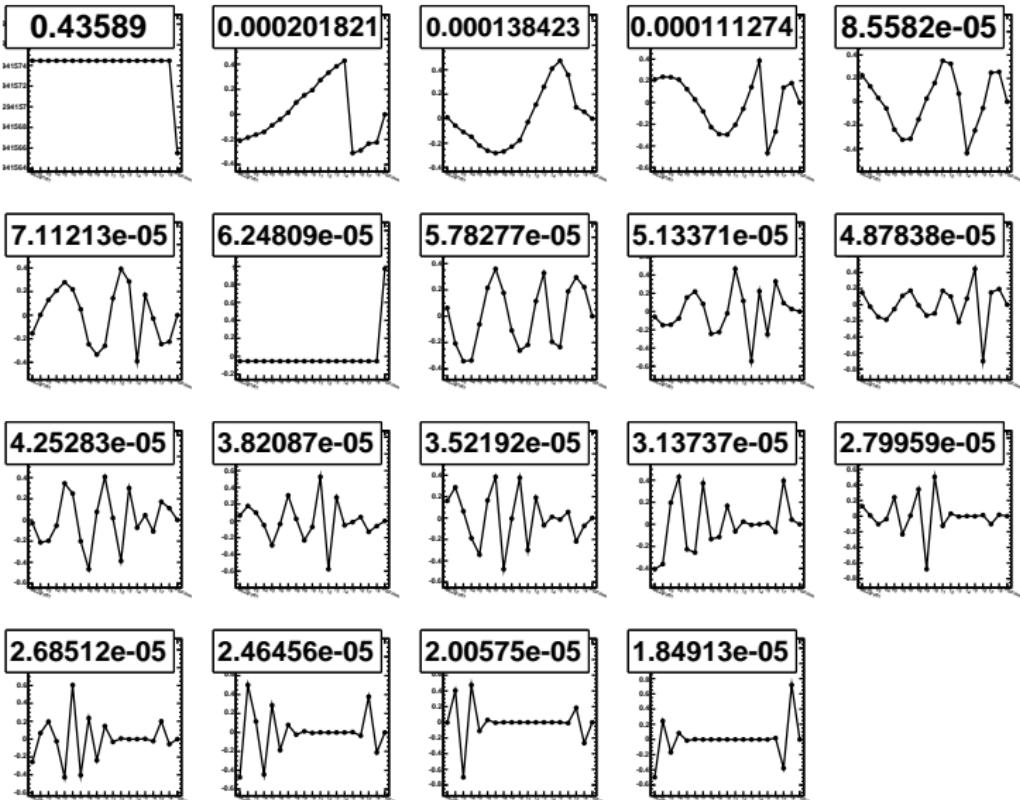


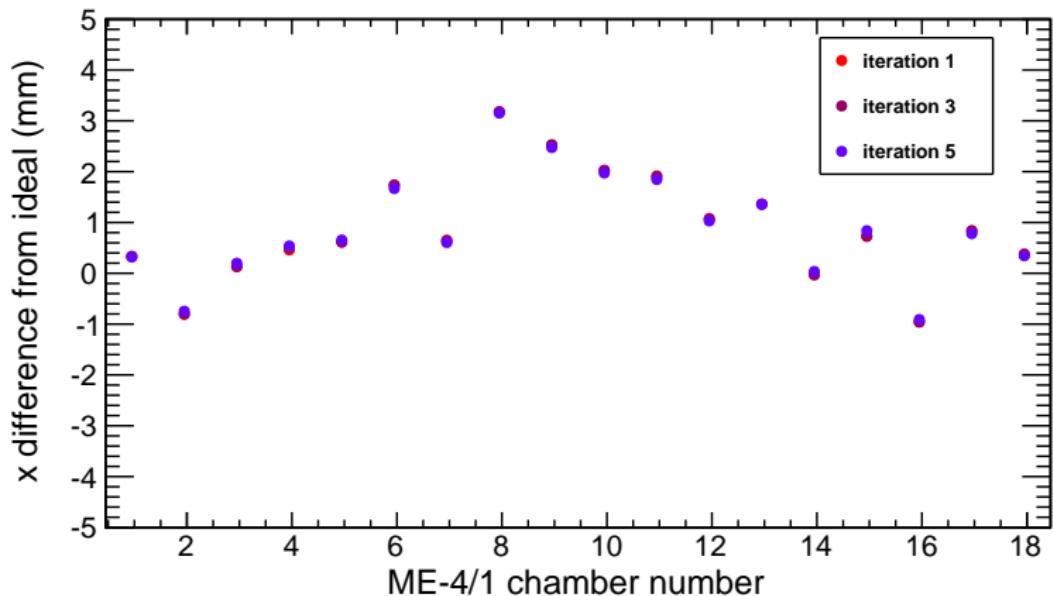
Convergence in ϕ_z angles

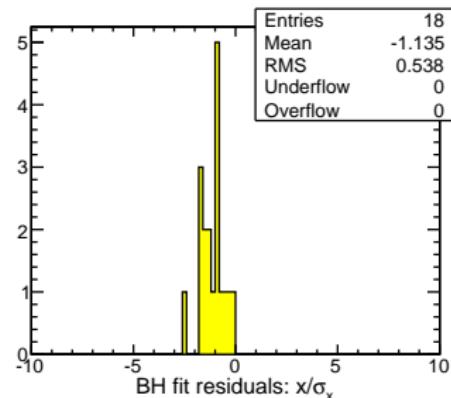
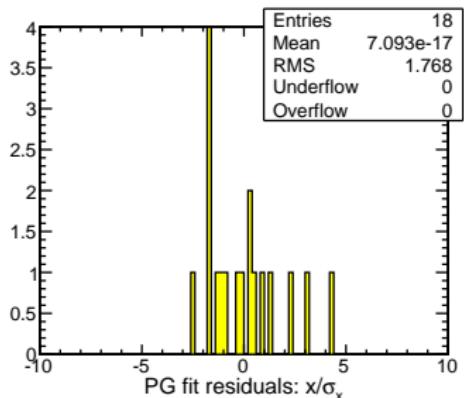
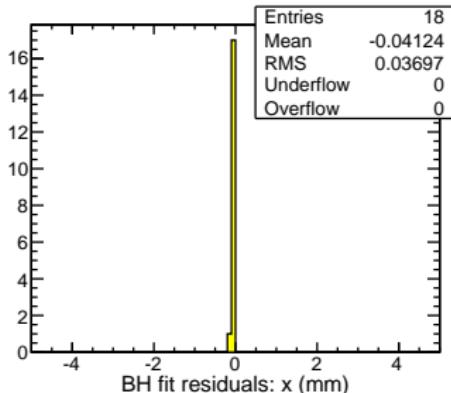
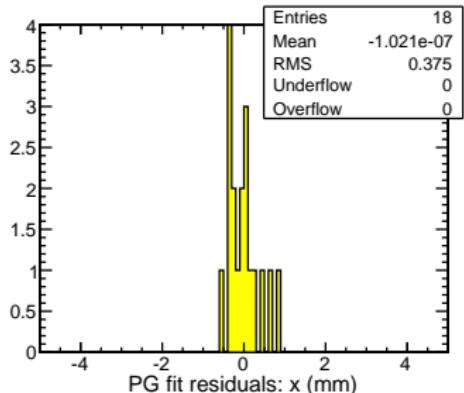
Fit residuals in ϕ_z (not track residuals)



Numbers in boxes are ϕ_z angle uncertainty in each mode in rad
First 1 is completely undetermined (uncertainty is meaningless)

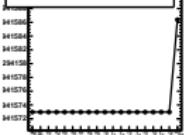
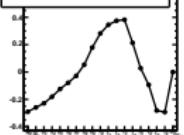
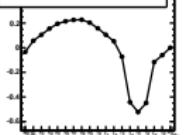
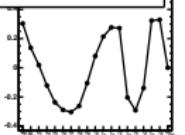
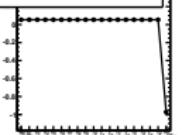
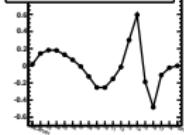
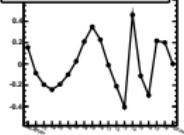
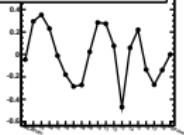
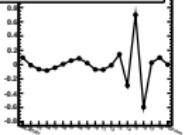
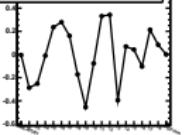
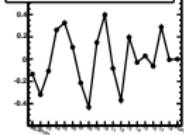
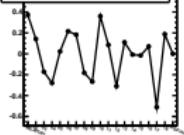
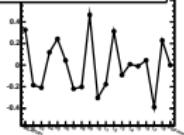
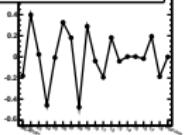
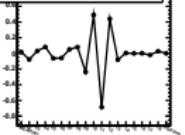
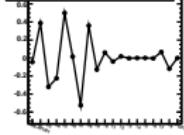
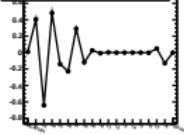
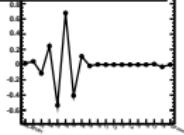
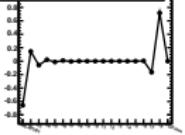


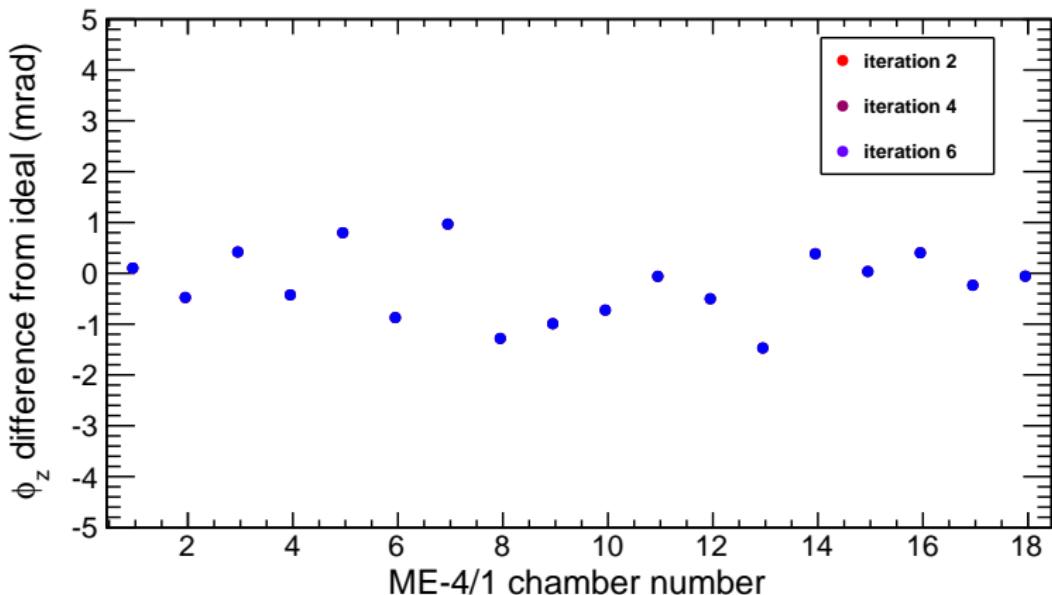
Convergence in $r\phi$ positions

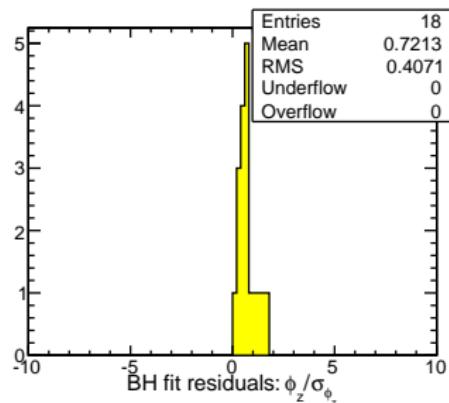
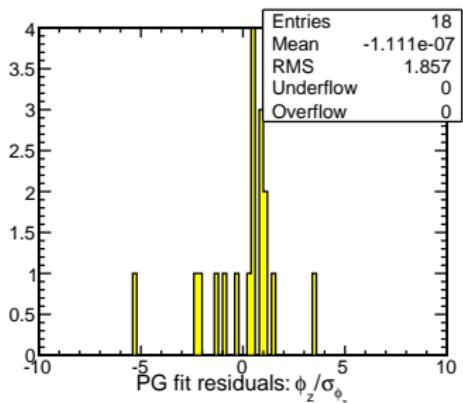
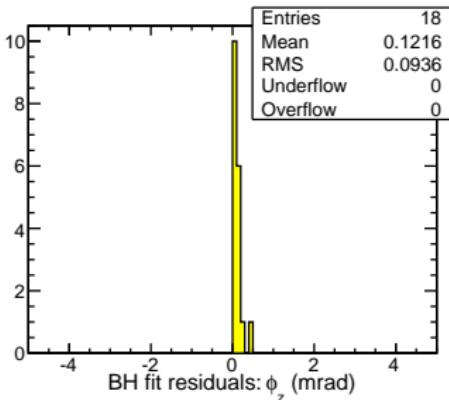
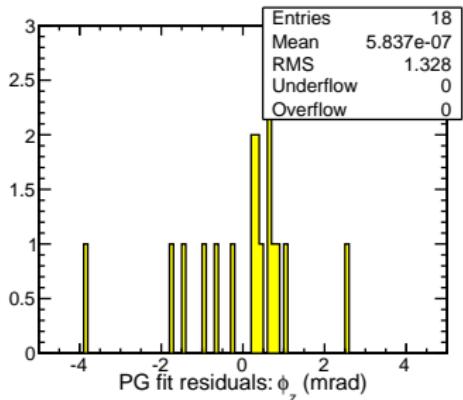
Fit residuals in $r\phi$ (not track residuals)



Numbers in boxes are ϕ position uncertainty in each mode in rad
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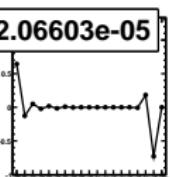
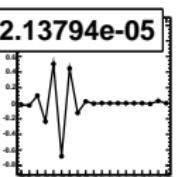
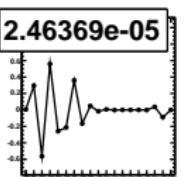
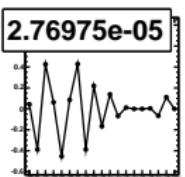
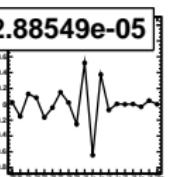
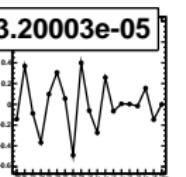
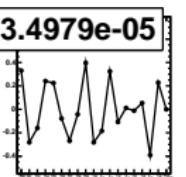
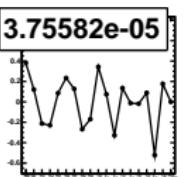
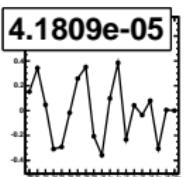
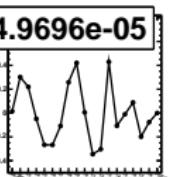
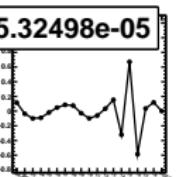
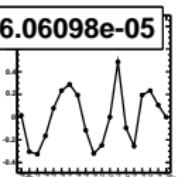
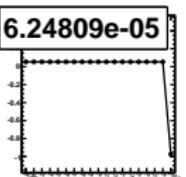
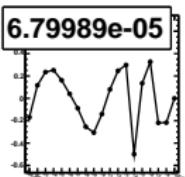
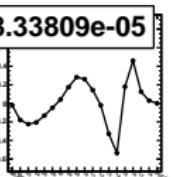
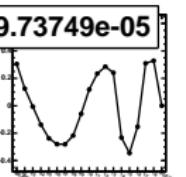
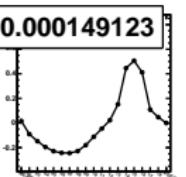
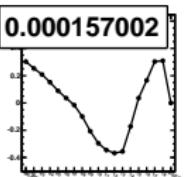
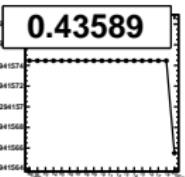
0.0242161**3.36465e-05****3.20439e-05****1.95732e-05****1.8529e-05****1.64084e-05****1.34127e-05****1.16853e-05****1.01971e-05****9.64458e-06****8.02337e-06****7.09203e-06****6.64259e-06****6.03243e-06****5.54857e-06****5.121e-06****4.53749e-06****3.98897e-06****3.75429e-06**

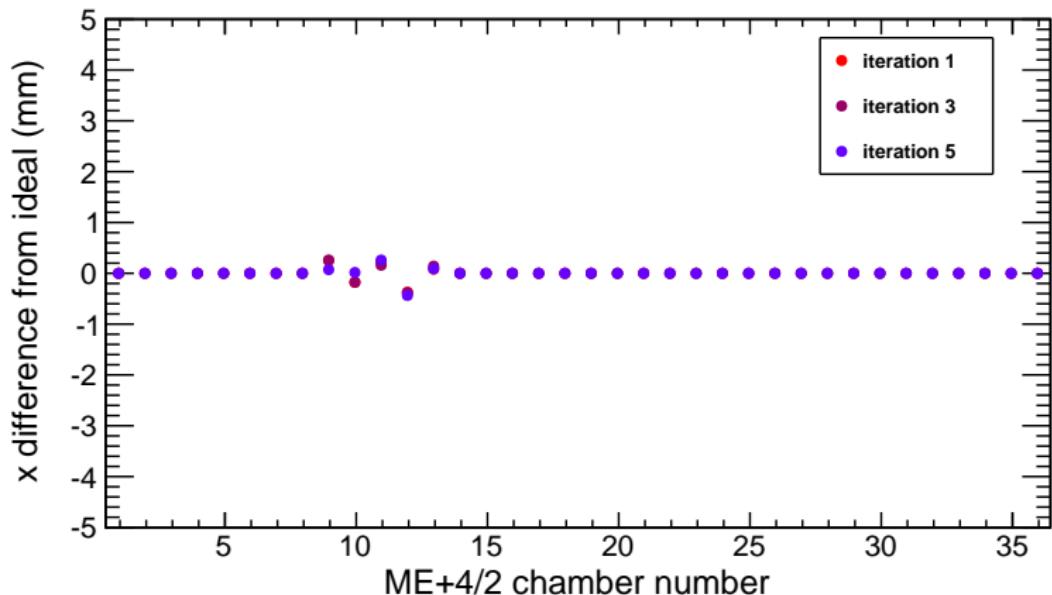
Convergence in ϕ_z angles

Fit residuals in ϕ_z (not track residuals)



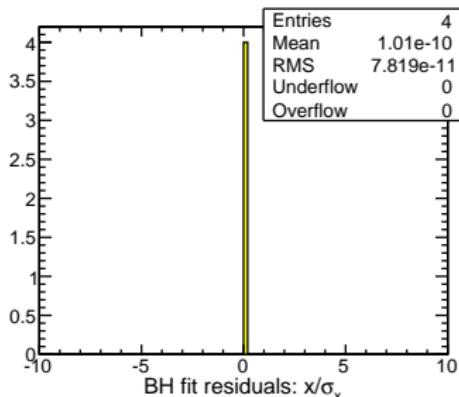
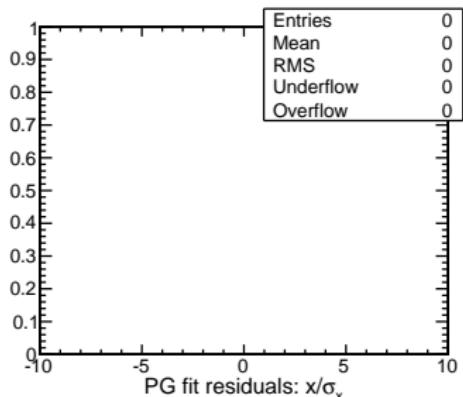
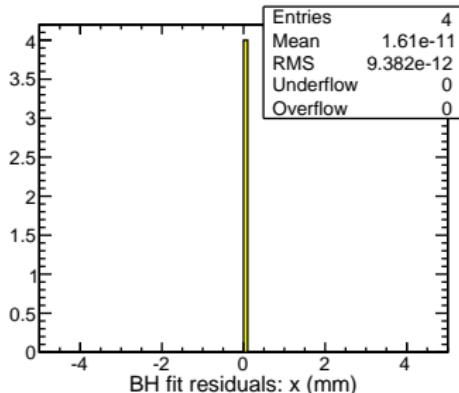
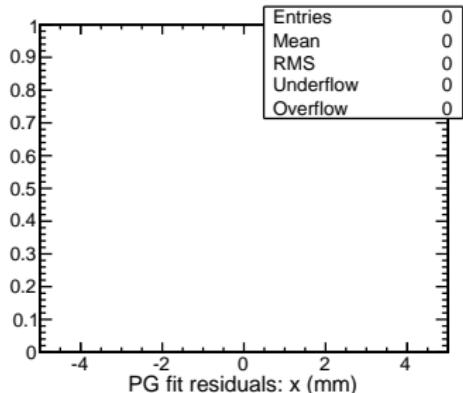
Numbers in boxes are ϕ_z angle uncertainty in each mode in rad
First 1 is completely undetermined (uncertainty is meaningless)



Convergence in $r\phi$ positions

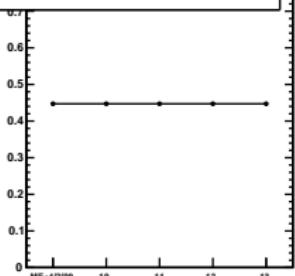
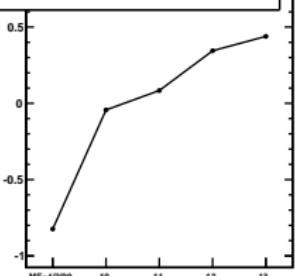
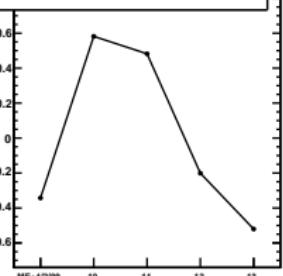
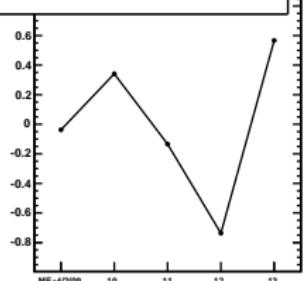
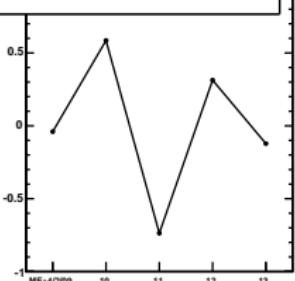


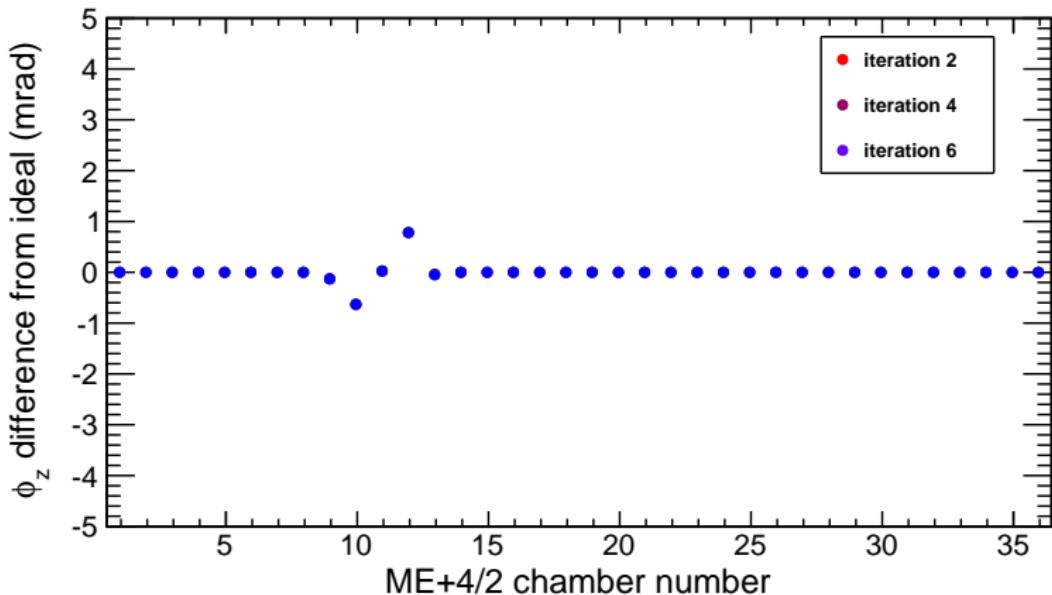
Fit residuals in $r\phi$ (not track residuals): no PG, perfect BH fit





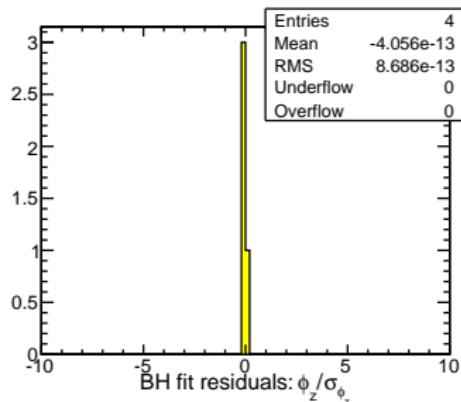
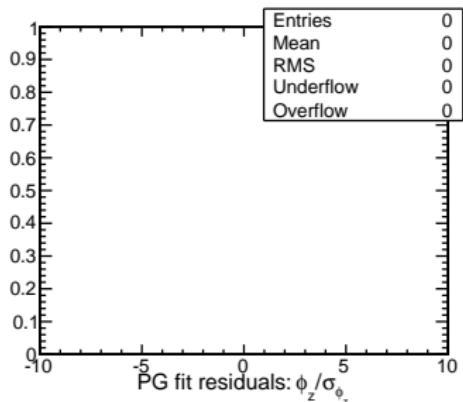
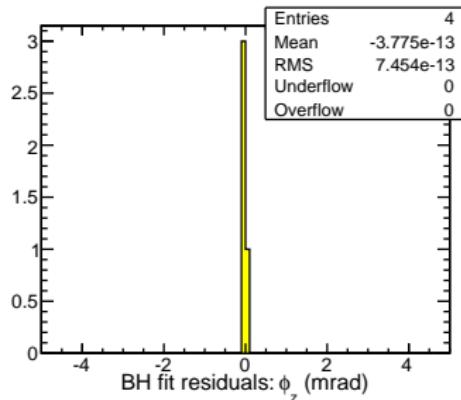
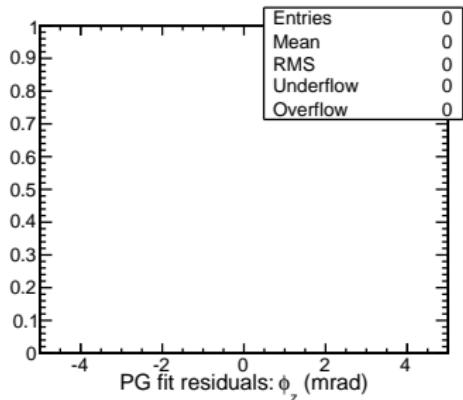
Numbers in boxes are ϕ position uncertainty in each mode in rad
First 1 is completely undetermined (uncertainty is meaningless)

0.0447214**6.35531e-05****3.76627e-05****1.94612e-05****1.56351e-05**

Convergence in ϕ_z angles

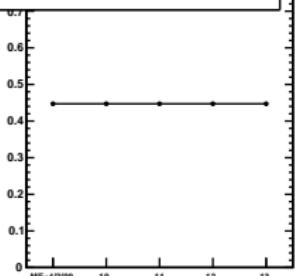
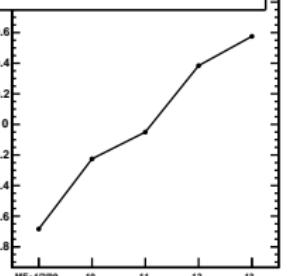
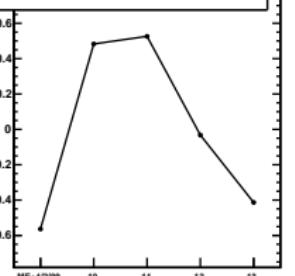
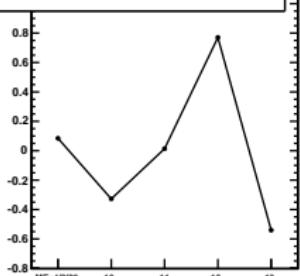
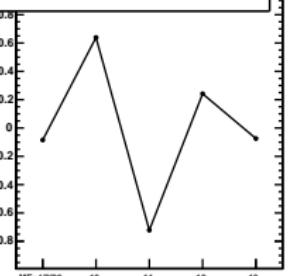


Fit residuals in ϕ_z (not track residuals): no PG, perfect BH fit



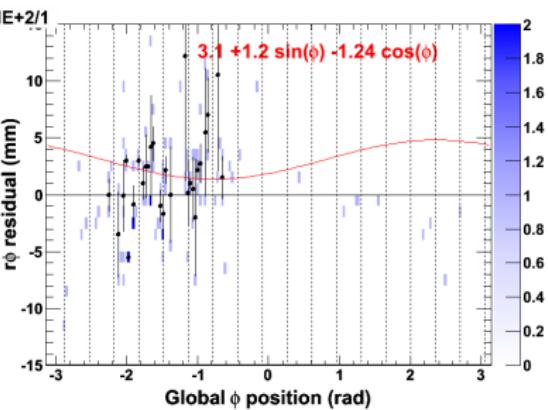
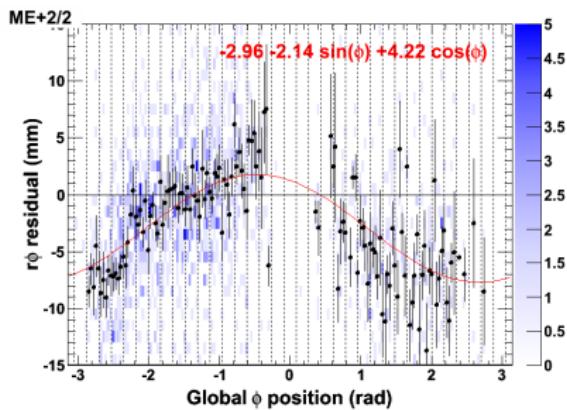


Numbers in boxes are ϕ_z angle uncertainty in each mode in rad
First 1 is completely undetermined (uncertainty is meaningless)

0.0447214**0.000279055****0.000167676****0.000103411****7.81854e-05**

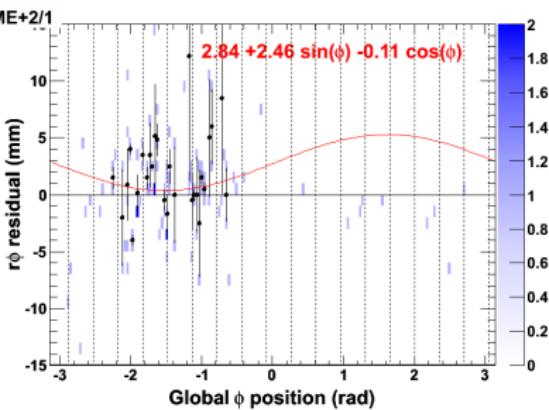
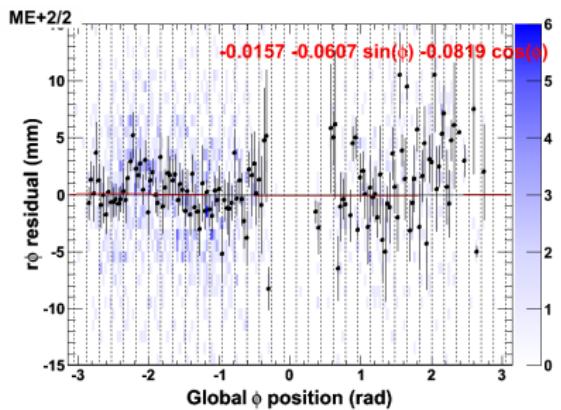


- ▶ Using 2010 cosmics, align large structures to tracker
- ▶ This is a test without the latest tracker and GlobalPositionRcd
- ▶ Inner ring alignment is not feasible with this dataset, so that's why we will combine disk statistics





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`/afs/cern.ch/user/p/pivarski/public/MAY14_CSC_beamhalo-PG.db`

However, this is not what goes into the database: we'll need to add the global disk positions

- ▶ definitely x , y , ϕ_z from globalMuons
- ▶ possibly z from other sources

Currently, all disk positions are from ideal geometry