ICOOL Acceptance Studies of Garren/Kirk Cooling Ring

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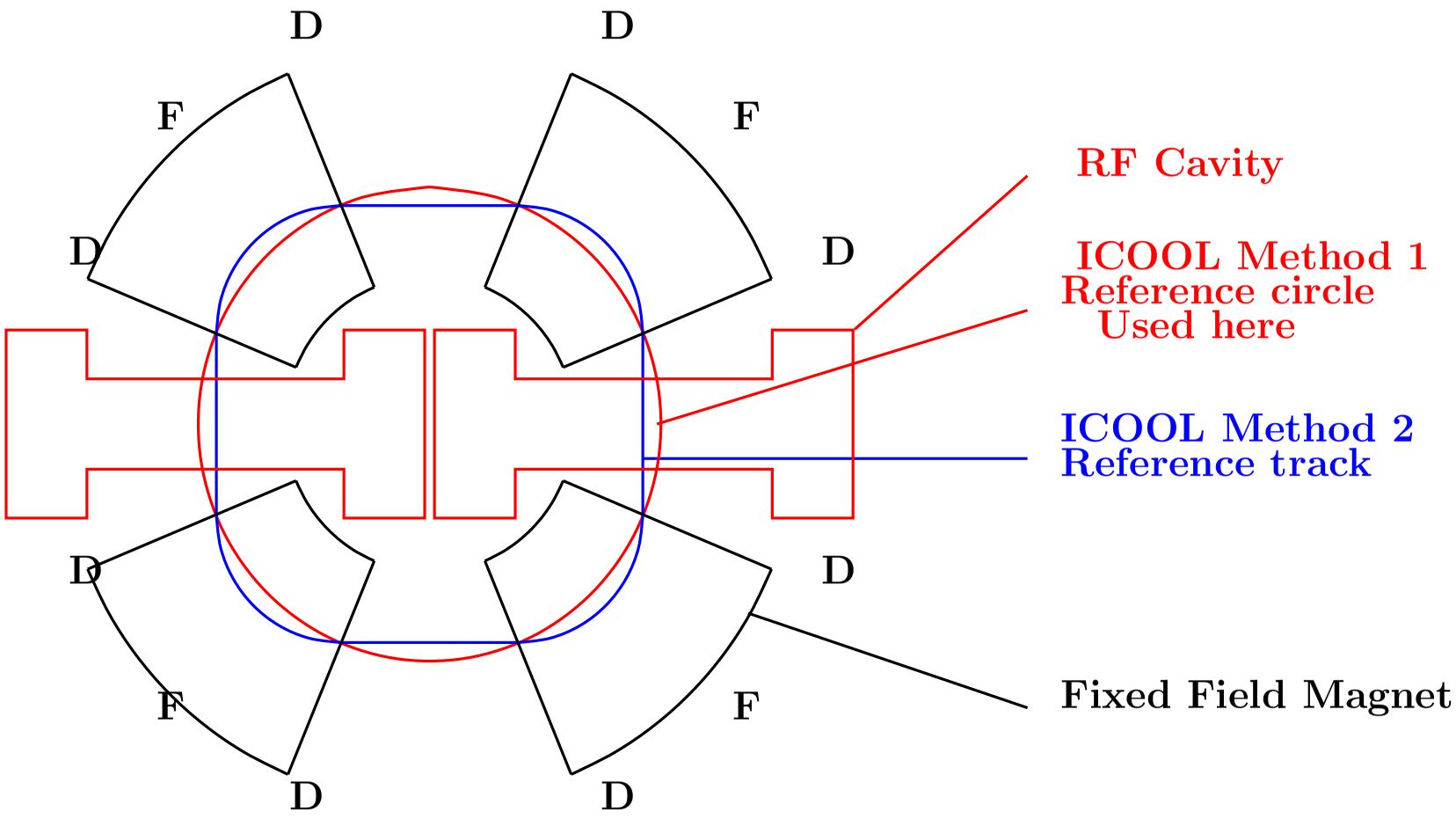
- 1) Initial Assumptions
- 2) Optimize Shape parameter
- 3) Pure Sine
- 4a) Add Field Gradient
- 4b) Optimize sine amplitude
- Conclusion

Garren/Kirk Cooling Ring



- H2 gas filled
- Pole angles ≡ D focus
- A "Scaling" FFAF, almost a scaling FFAG

ICOOL Method

Magnets are assumed to have hyperbolic tangent fall offs

$dz_i = z_i/\Gamma$ and nominal field B_o:

$$B = \frac{B_o}{2}\left\{\frac{(e^{dz_1} - e^{-dz_1})}{(e^{dz_1} + e^{-dz_1})} - \frac{(e^{dz_2} - e^{-dz_2})}{(e^{dz_2} + e^{-dz_2})}\right\}$$

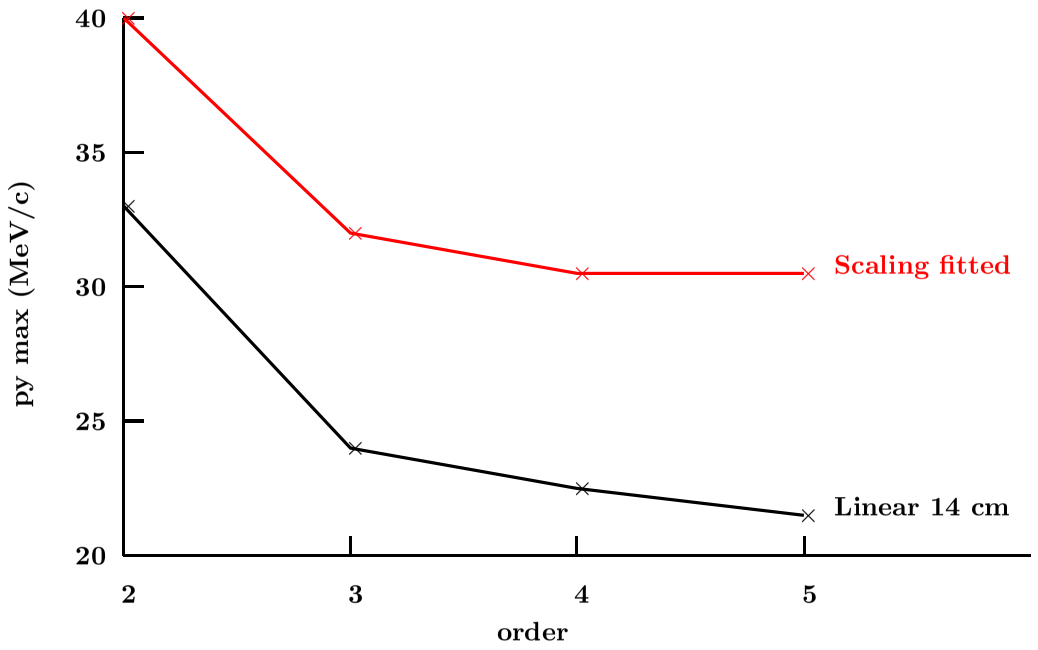
These are then Fourier transformed, using 50 coefficients
By limiting the number of components the fields can be "smoothed"
Maximum smoothing = pure sine z variation

Above fields are those on a true circular reference "orbit"

Fields off this reference are calculated from Maxwell's Equations, to a given order

Sensitivity to Order of ICOOL Field Calculation

2 examples from a PRISM Study:



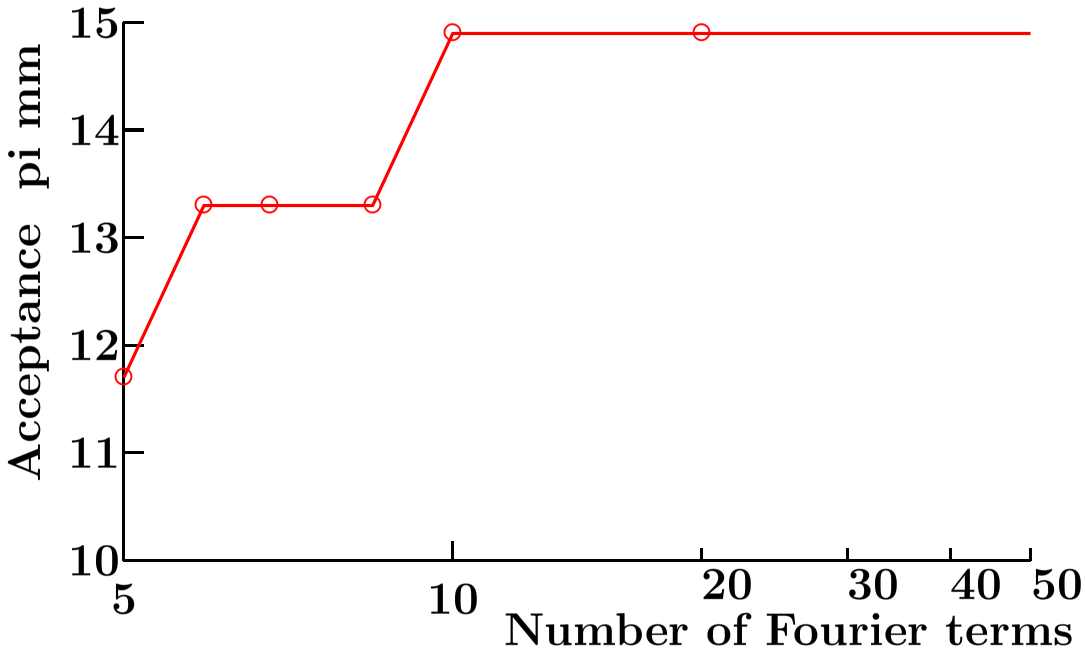
Probably less than 2% error for 5th order calculation

Use:

order=5

turns=10

Sensitivity to Number of Fourier Terms

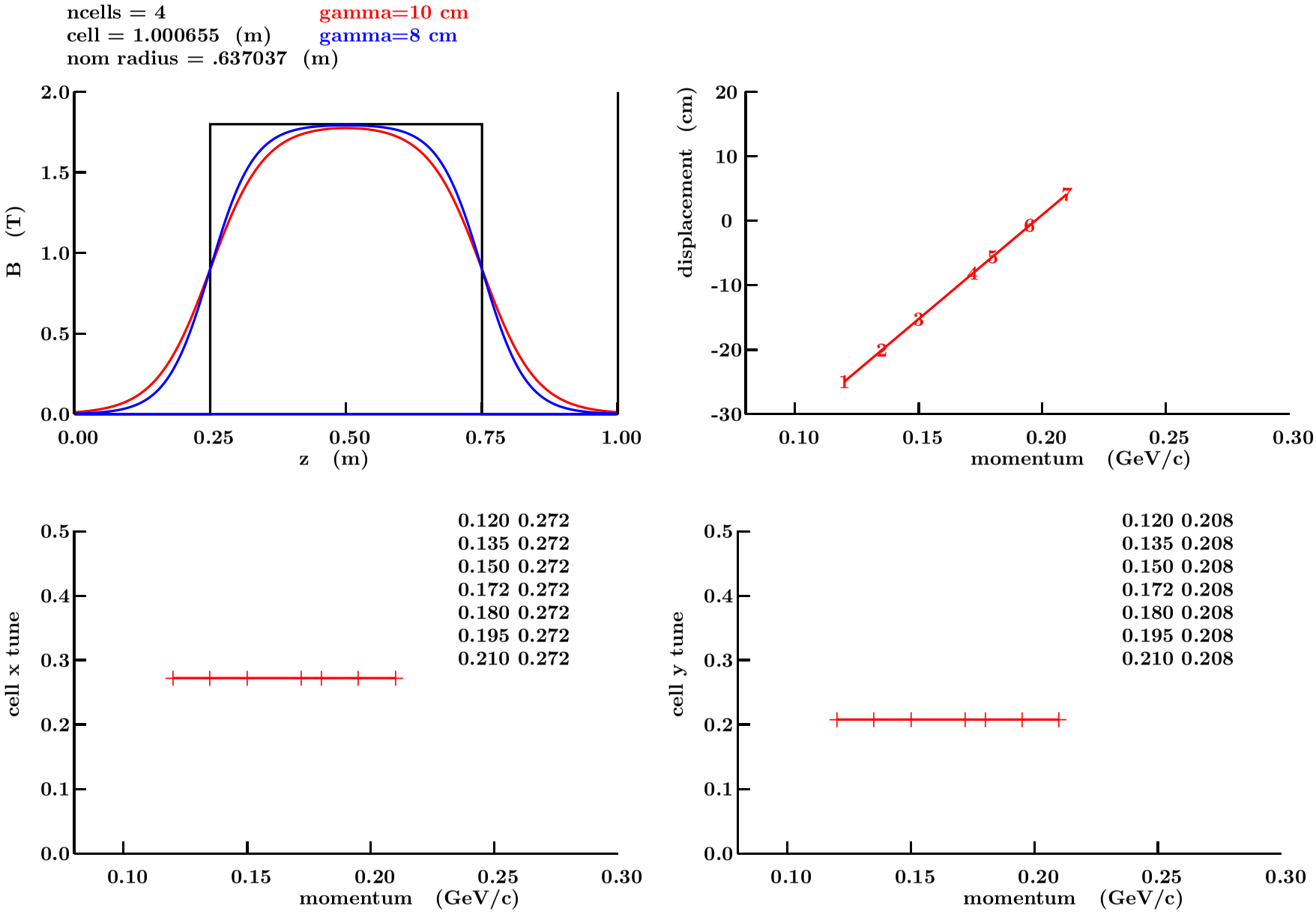


50 terms seems more than adequate

Parameters Used for All Calculations

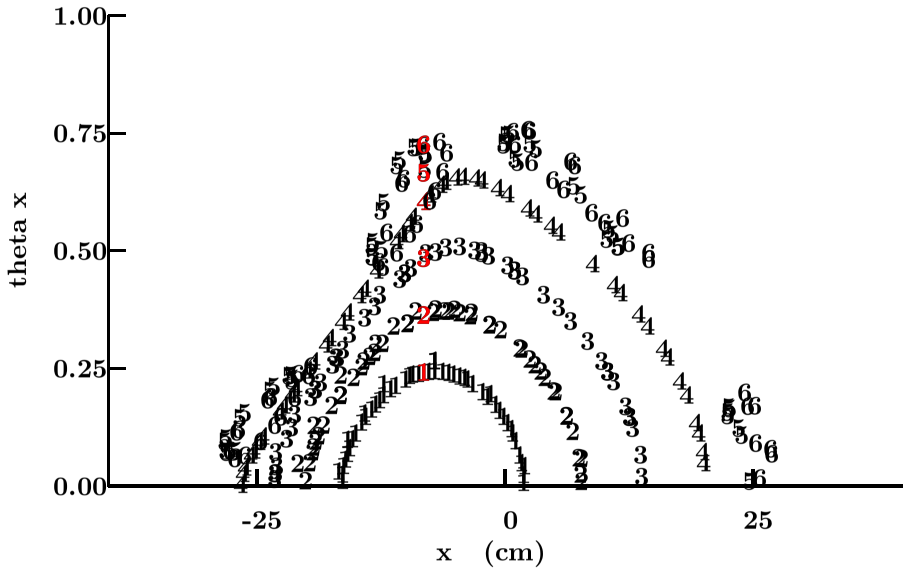
n cells = 4
Central Momentum = 172 MeV/c
Cell Length = 1.000655 (m)
Magnet Length = 1.000655/2 (m)
Nominal radius = .637037 (m)

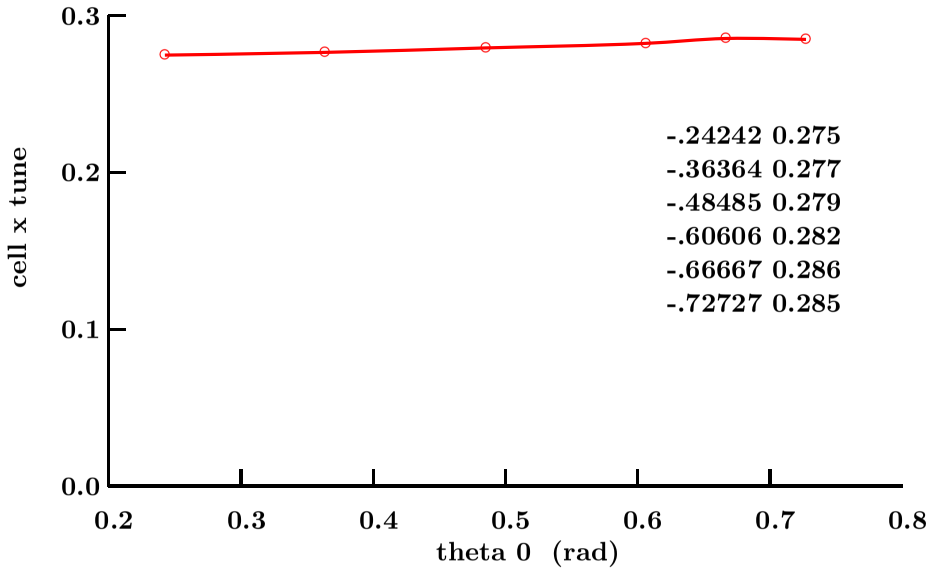
1) Initial Run: Gamma= 10 cm



Tunes are flat, so it is "Scaling"

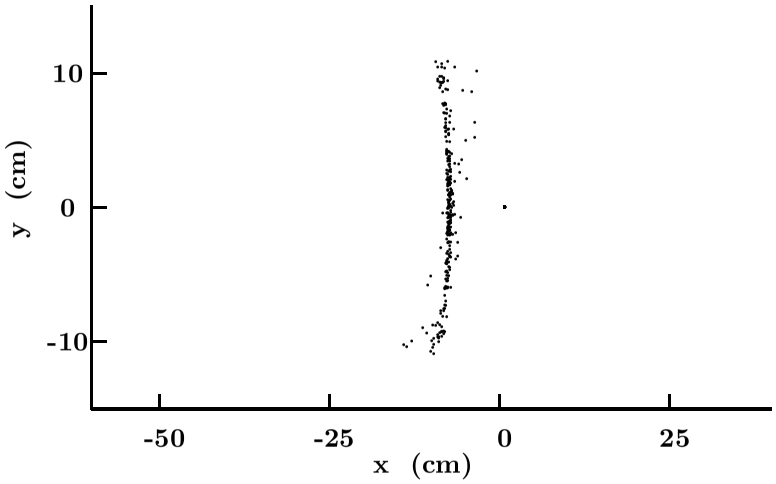
Vary Initial x amplitude

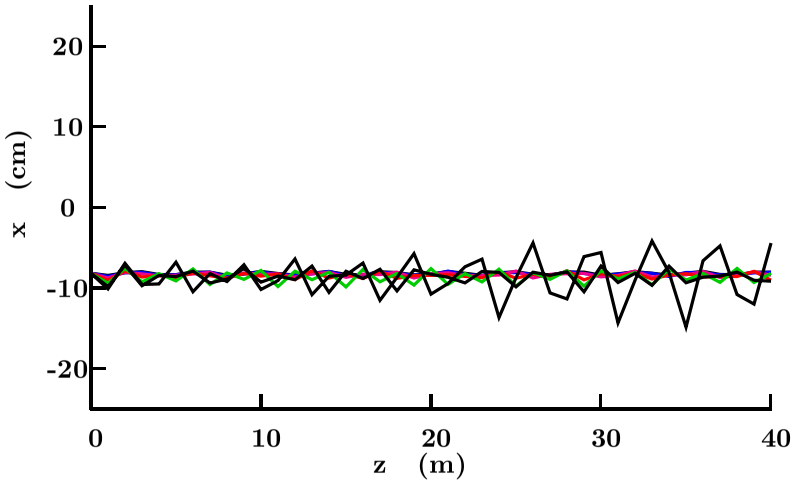


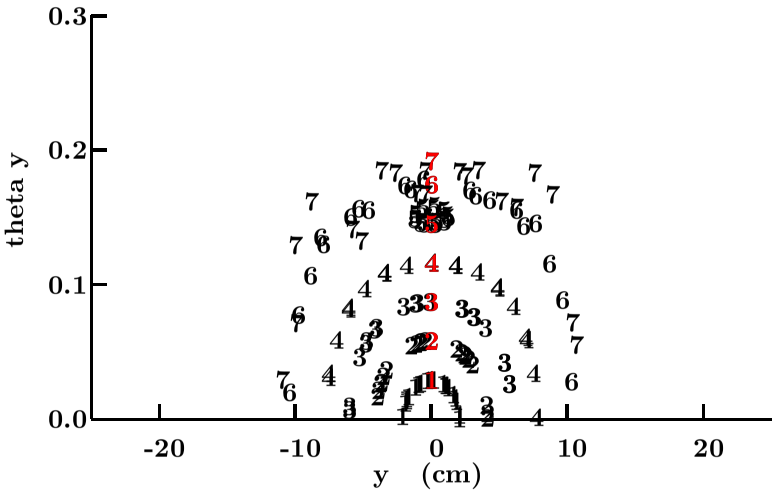


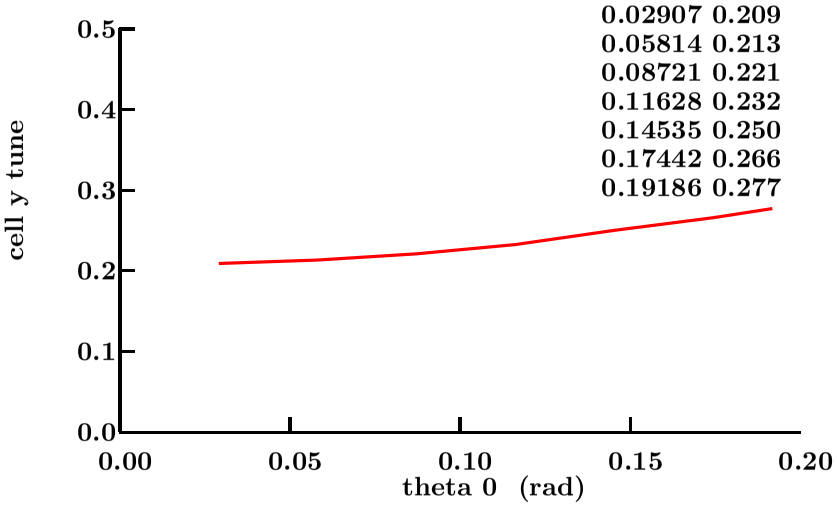
- Very large Acceptance in x
- y tune depends little on amplitude

Vary Initial y amplitude



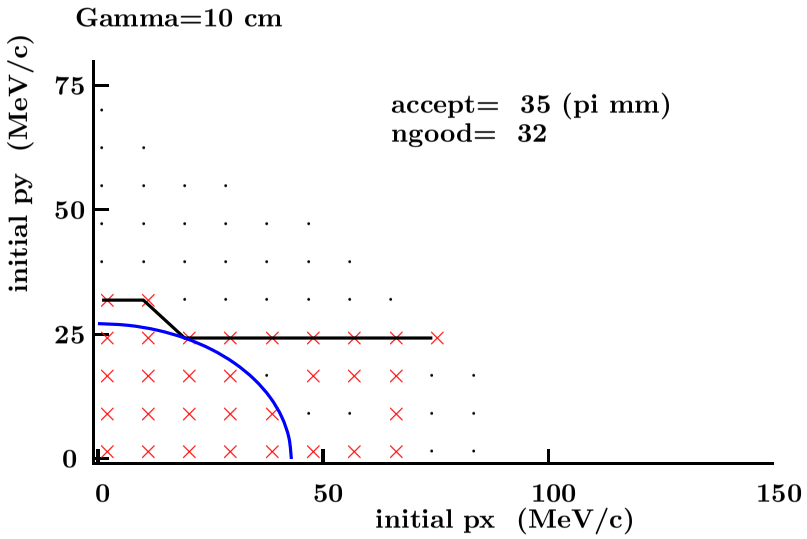


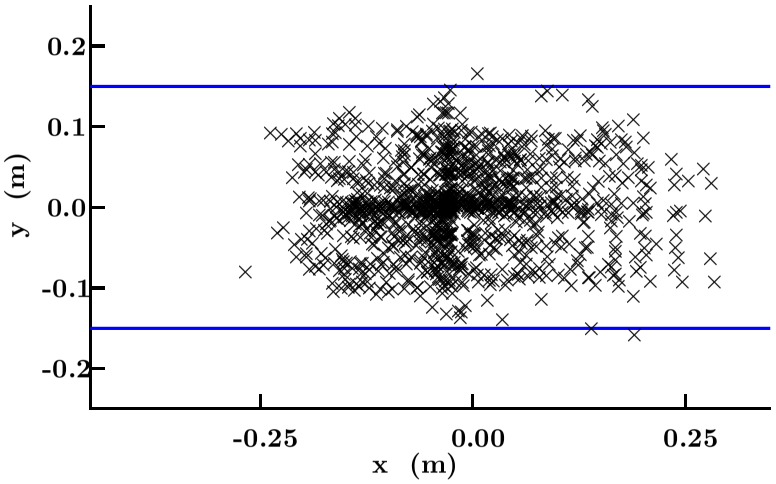




- Significant x-y mixing and less y acceptance than in x
- y tune depends on amplitude
- resonance as y tune=.25, but no loss

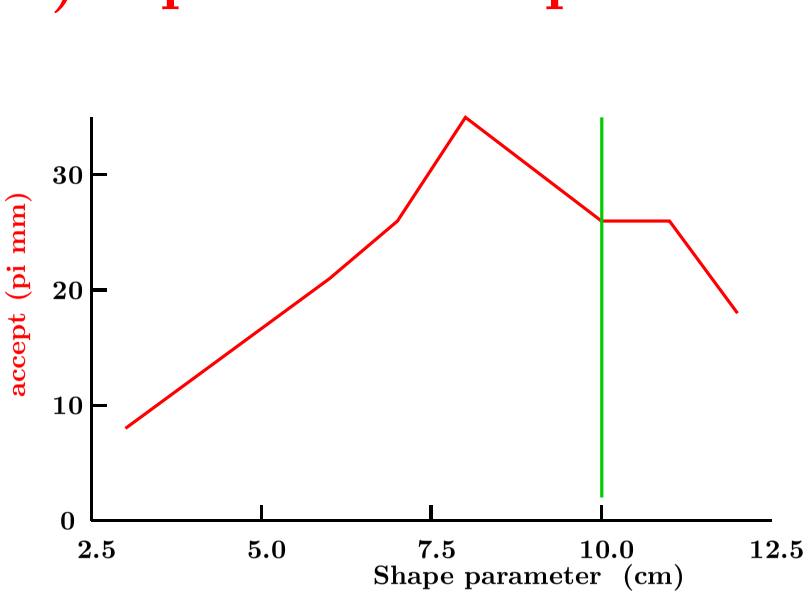
Aperture in x and y simultaneously

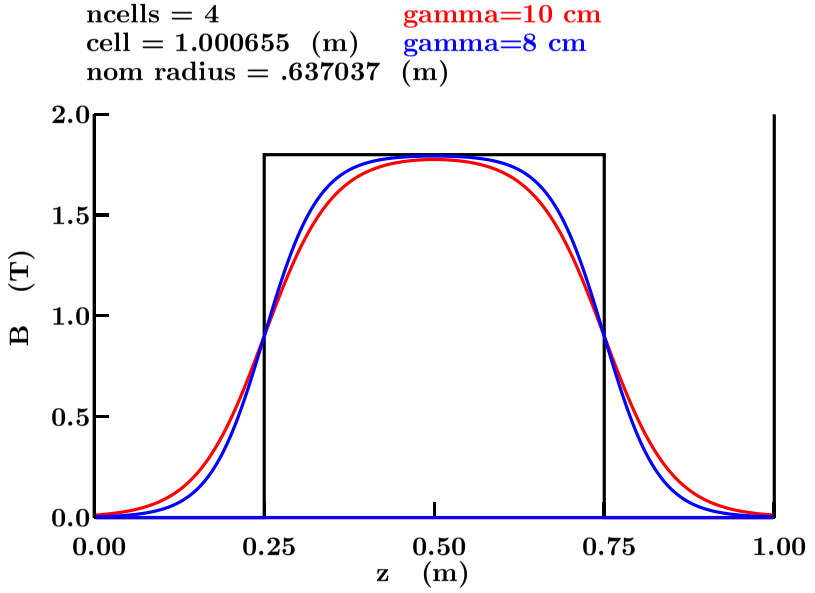


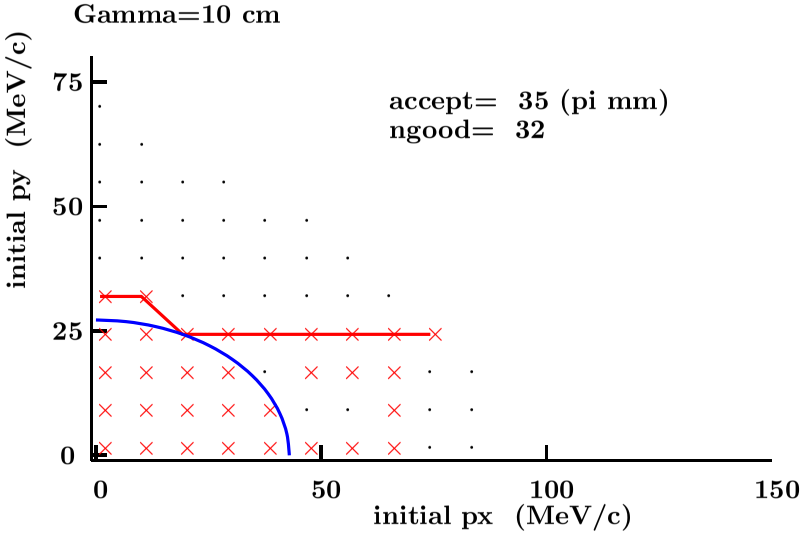


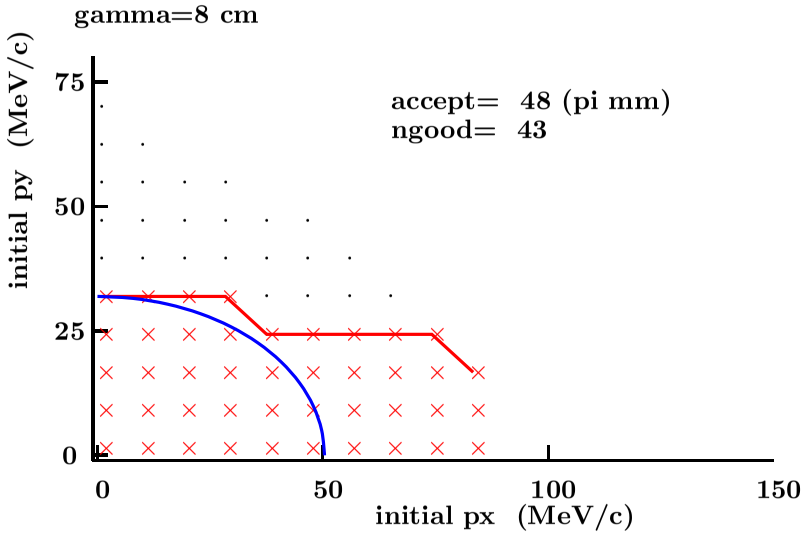
- Ellipse is for maximum equal acceptance in x and y
- y acceptance does not fill vertical aperture
- Very large x acceptance only for very small y amplitudes
- Acceptances significantly less than "hard edged" calculations

2) Optimize Shape Parameter Gamma



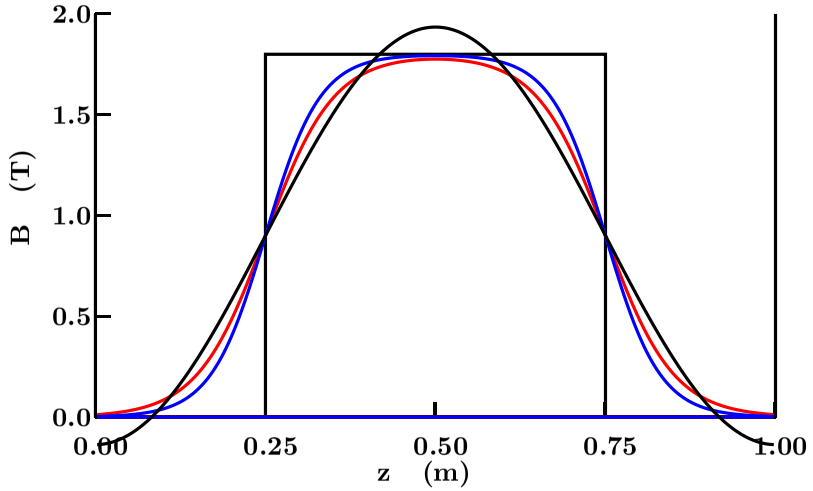




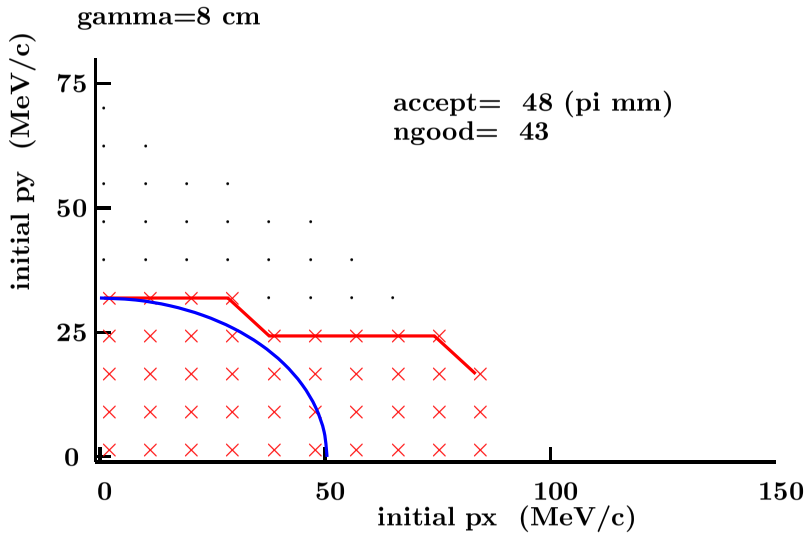


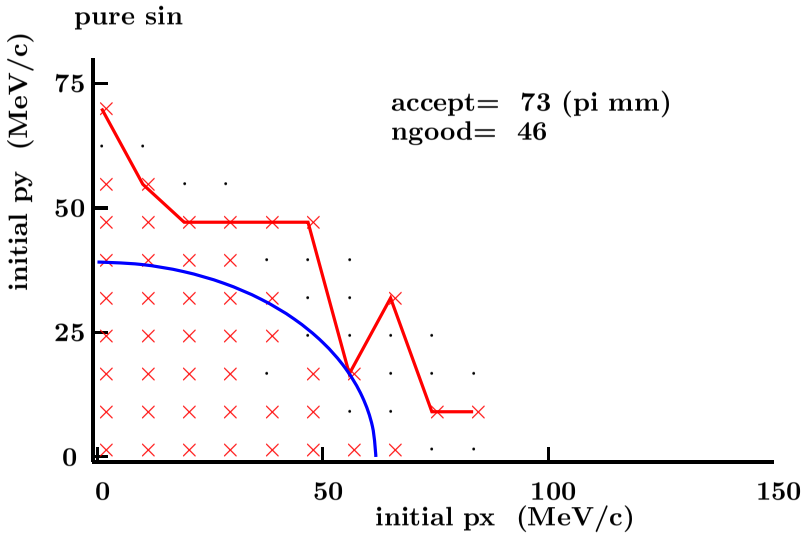
- 8 cm better than 10 cm but how?
- Acceptance improved 37 %

3) Try pure sine variation with azimuth



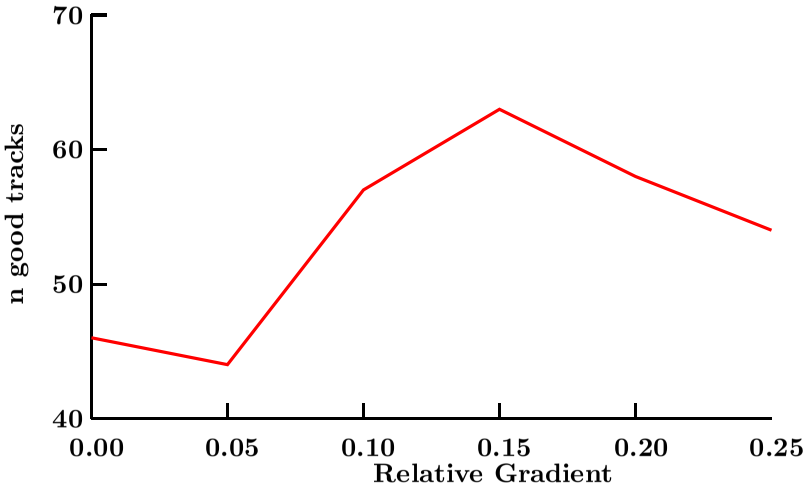
gamma=10 cm
gamma=8 cm
pure sin





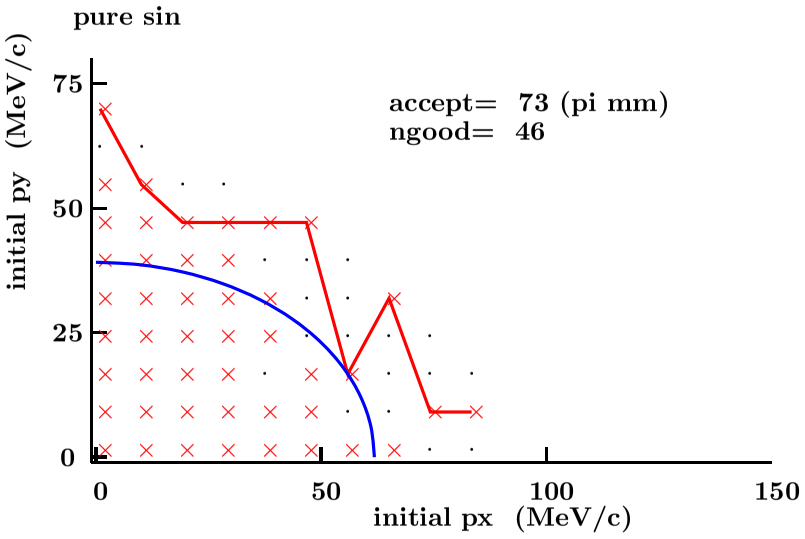
- Acceptance much better in y
- less acceptance in x
- Acceptance improved by 52 %

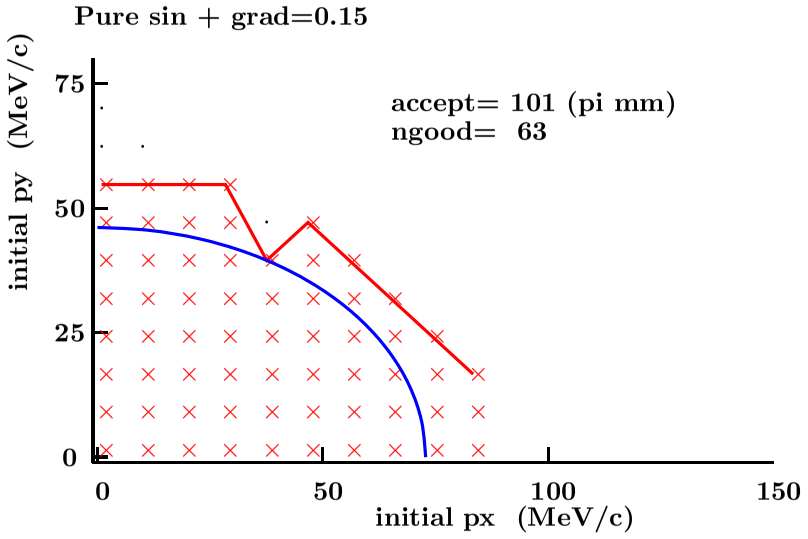
4a) Add B gradient



Best Field gradient

$$\text{Grad} = \frac{0.15\ \text{B}}{\text{R}} = \frac{0.15\ 1.8}{.637} = 0.42\ (\text{T/m})$$

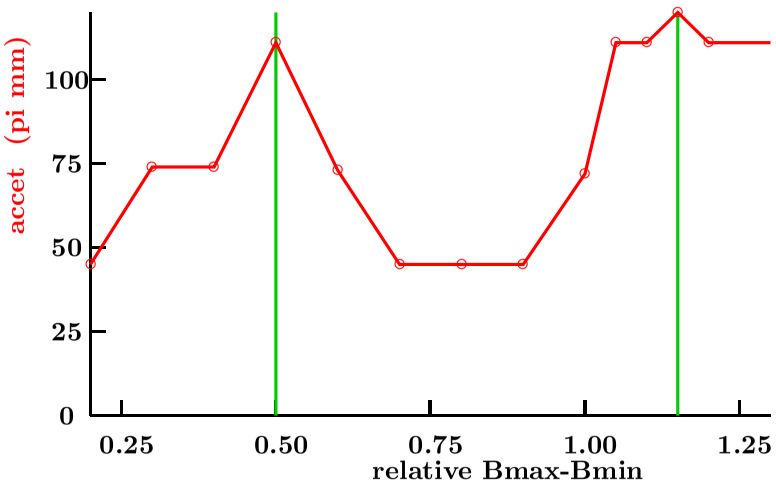


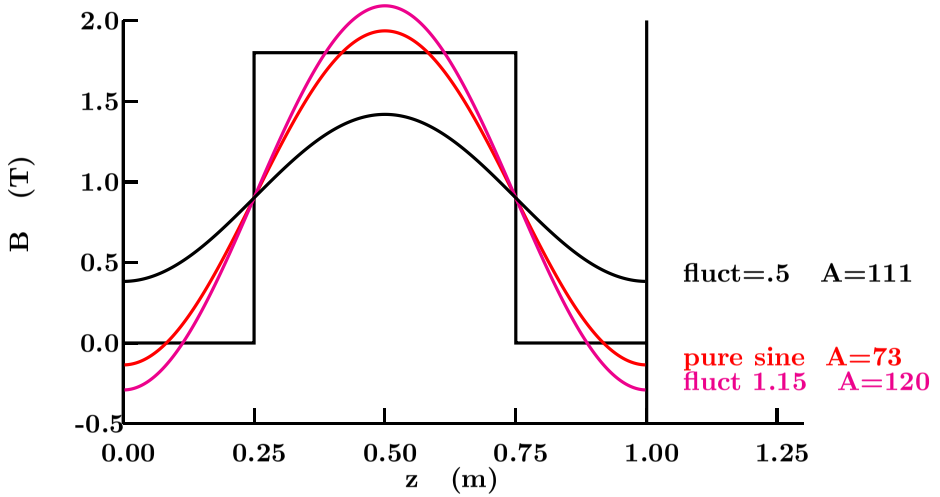


- Now good in x and y
- Acceptance improved by $> 40\%$

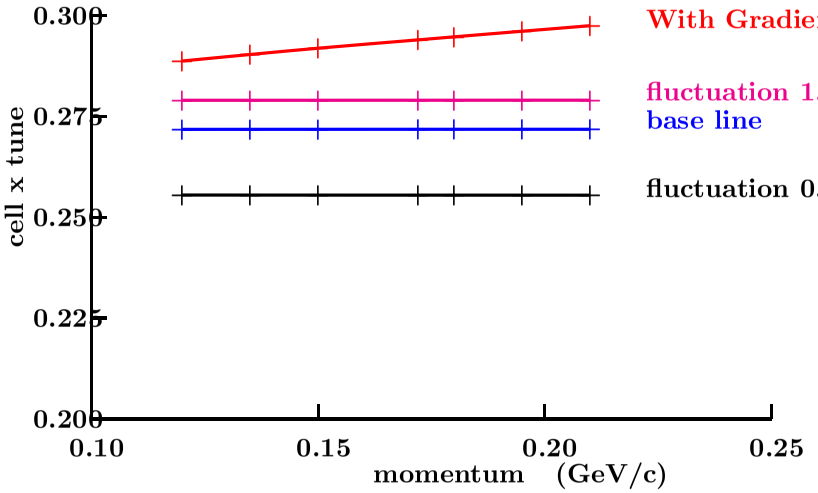
4b) Vary amplitude of sine variation

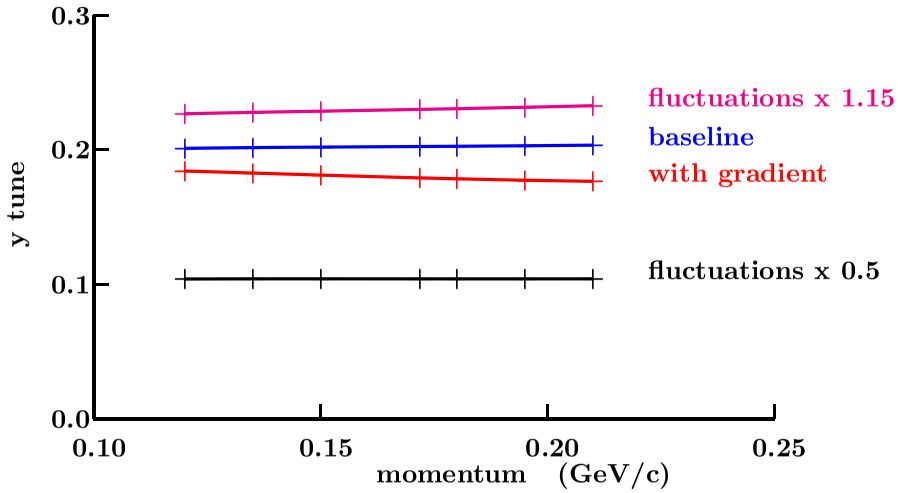
But keep gradient=0





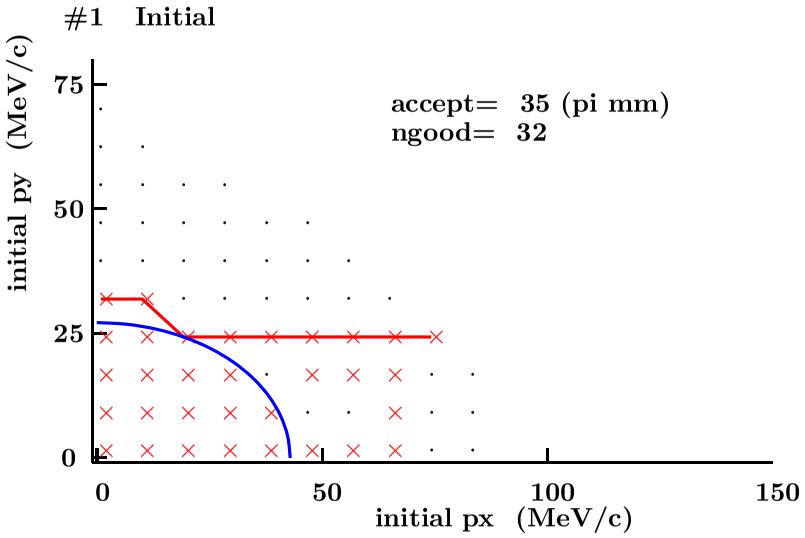
2 solutions, but lower has low ν & high β (bad for cooling)

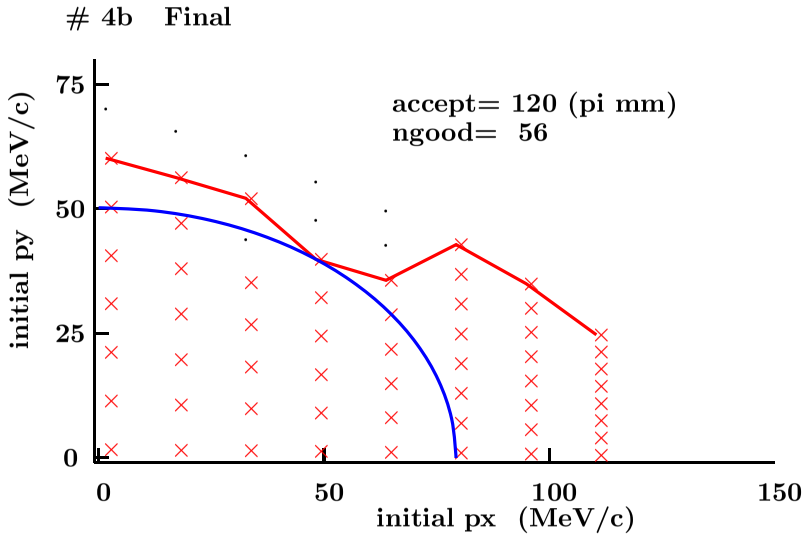




- Acceptance improved by further 20%

Compare Initial (# 1) with Best (# 4b)





- Acceptance improved by factor 3.4

Also Tried

- 6 poles instead of 4
  Worse
- Gradient instead of Pole angles
  Much Worse Needs study

Summary

case		grad rel.	sine amp. rel.	x tune	y tune	Accept pi mm	Gain
1	10 cm Gamma	0	1	.272	.203	35	1
2	8 cm Gamma	0	1	.272	.203	48	1.4
3	Sine Wave	0	1	.272	.203	73	2.1
4a	Sine Wave + G	0.15	1	.272	.203	101	2.9
4b	Enhanced sine	0	1.15	.279	.230	120	3.4
7	6 Pole	0	1			94	
8	Weak Focus	0	1			11	

Conclusion

- Large gain in acceptance for
  Pure Sine Field Variation with z
- Significant gain with some positive field gradient
- Even greater gain if sine fluctuation enhanced (How?)
- No gain with more poles
- For two cases (4a and 4b), acceptance limited by physical aperture rather than dynamics
- But inside and outside fall offs of B with rad not yet included