Beam aspect ratio and FastMC acceptance

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Goal: Determine if there is a statistically significant difference in signal yield and S/B between various aperture ratios to a precision of $\sim 10\%$**.**

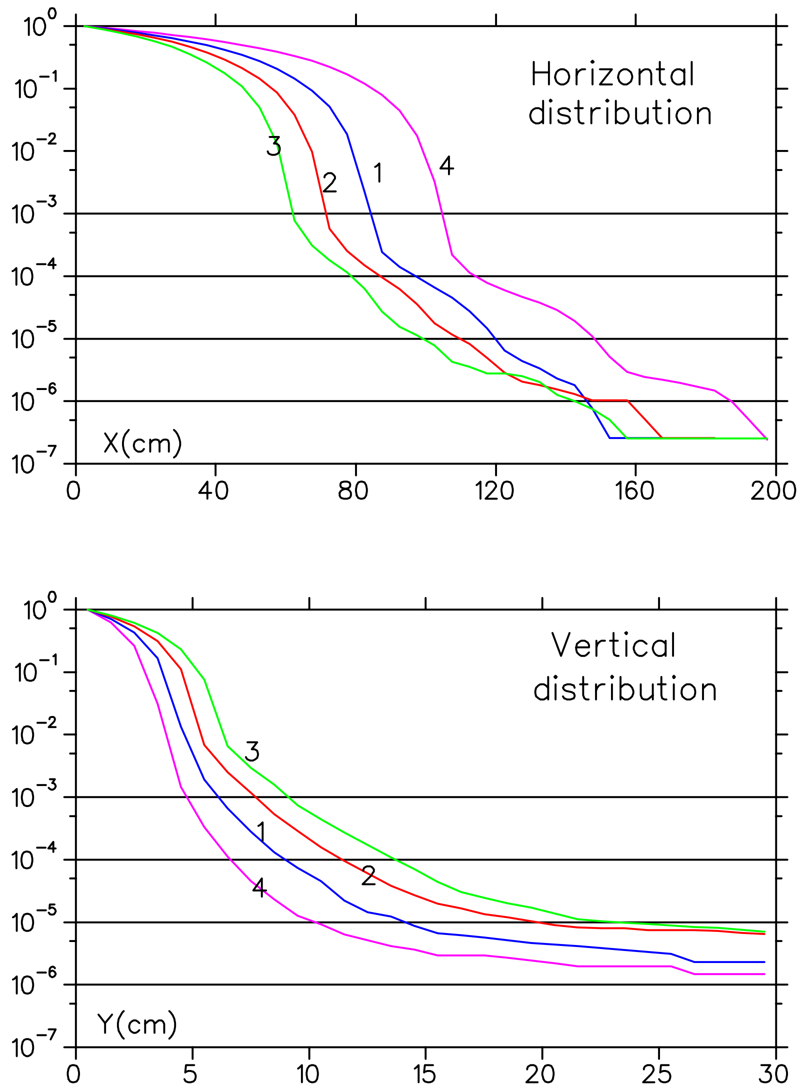
- Review of TN049
- Definition of apertures
- Comparison of PR models
- Results
- Discussion

Review of TN049

TN049 is “Comparison of the neutron halos for 4 different x-y aspect ratios, for momenta above 750 MeV/c”, Jaap Doornbos, 14 Feb 2003.

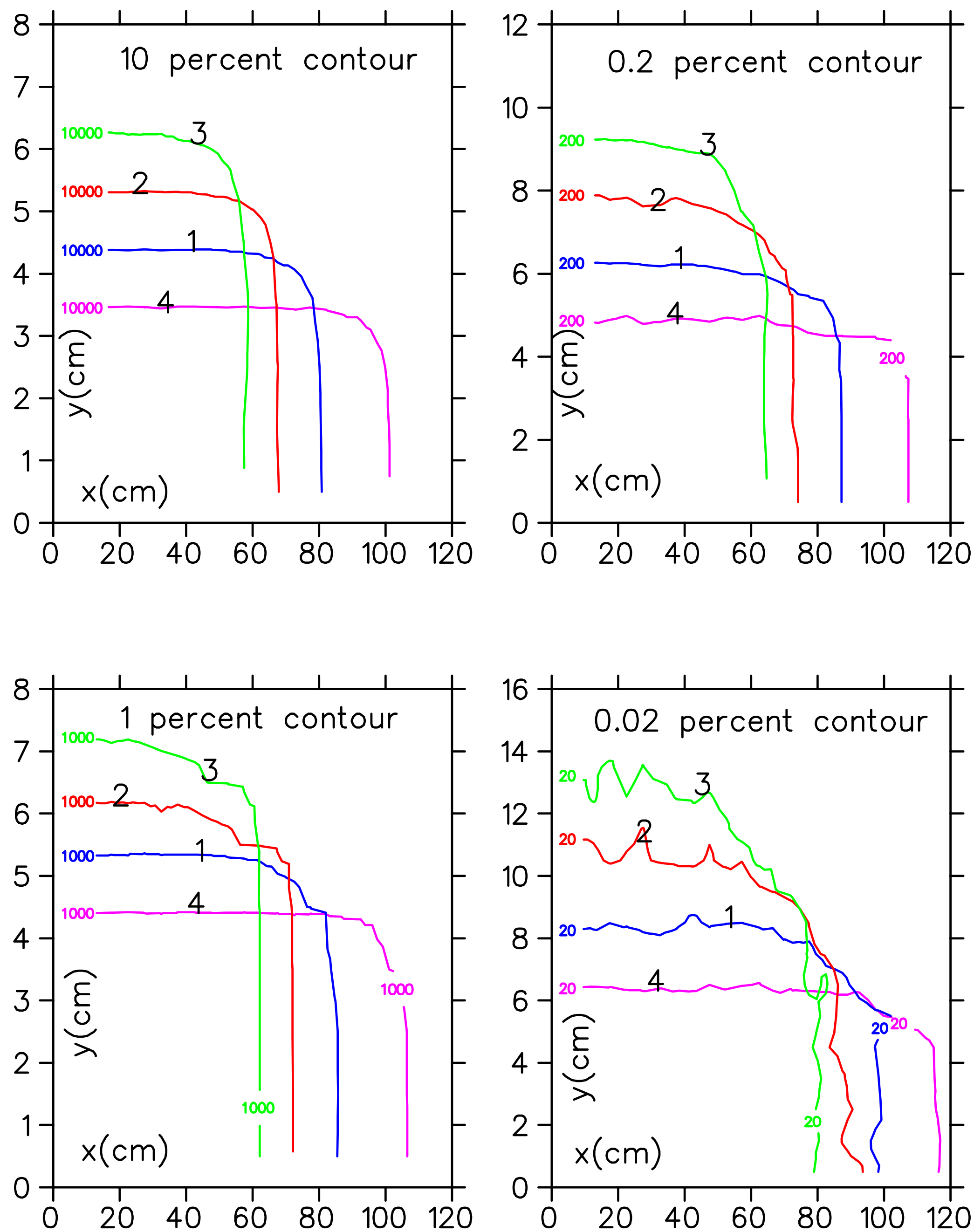
Jaap’s note assumes an extended target and beam to define beam aspect ratios.

Figure 19: Fraction of beam outside the areas, indicated on the horizontal axis.



Review of TN049

Figure 20: Contour plots at 14 m.



Aperture definitions

I used Figure 19 from TN049 to determine the x and y values at Z=1400 cm where the neutron halo was 10^{-4} of the beam.

I corroborated these values with the lower, right hand plot of Figure 20 from TN049 (0.02% contour).

The results are summarized in the figure on the next page.

Aperture definitions at Z=1400 cm

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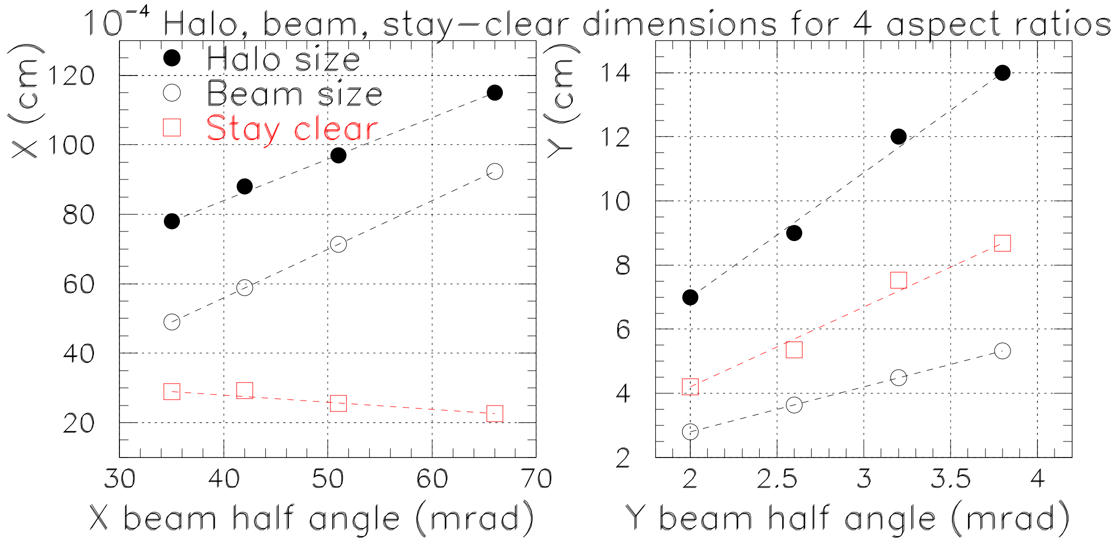


Aspect ratio	ΘX	ΘY	HaloX	HaloY	BeamX	BeamY	ClearX	ClearY	FidSiz
4	66	2	115	7	92.4	2.8	22.6	4.2	19280
3	35	3.8	78	14	49	5.32	29	8.68	18132
2	42	3.2	88	12	58.8	4.48	29.2	7.52	18276
1	51	2.6	97	9	71.4	3.64	25.6	5.36	19008

ΘX,ΘY in mrad, others in cm, FidSiz in cm^2

Θ_x, Θ_y = beam half angle,

BeamX,BeamY = beam half size,

HaloX,HaloY = X,Y position where Halo/Beam= 10^{-4},

ClearX,ClearY = clearance = Halo −Beam,

FidSiz = fiducial size of PR front face assuming outer limits $150 \times 150\text{cm}^2$

Aperture definitions for the FastMC

The FastMC assumes a point source for KL, so I redefined the beam aspect ratios.

I based my redefinition on $\Theta_x \times \Theta_y = 50 \times 2.5$ as the aspect ratio for the beam used in the TDR and I assume that this aspect ratio corresponds to Jaap's aspect #1. To obtain Θ_y for the FastMC for aspect #2, I scaled by the Jaap's ratios of Θ_y for aspects #1 and #2. Then I set Θ_x such that the solid angle, $\Delta\Omega$, is 500 μSR.

	Jaap		FastMC		
	milliradians				μSR
Aspect#	Θ_x	Θ_y	Θ_x	Θ_y	$\Delta\Omega$
1	51	2.6	50	2.5	500
2	42	3.2	40.625	3.077	500.01
3	35	3.8	34.2105	3.654	500.02
4	66	2.0	65	1.923	499.98

I use the clearances derived from Jaap's results at Z = 1400 cm and the FastMC beam aspect ratios (above) to define the inner aperture at **Z = 1350 cm**, the front of the PR.

More definitions

For the rest of the talk, I will refer to aspect ratios in terms of the **full** opening angles instead of the half opening angles.

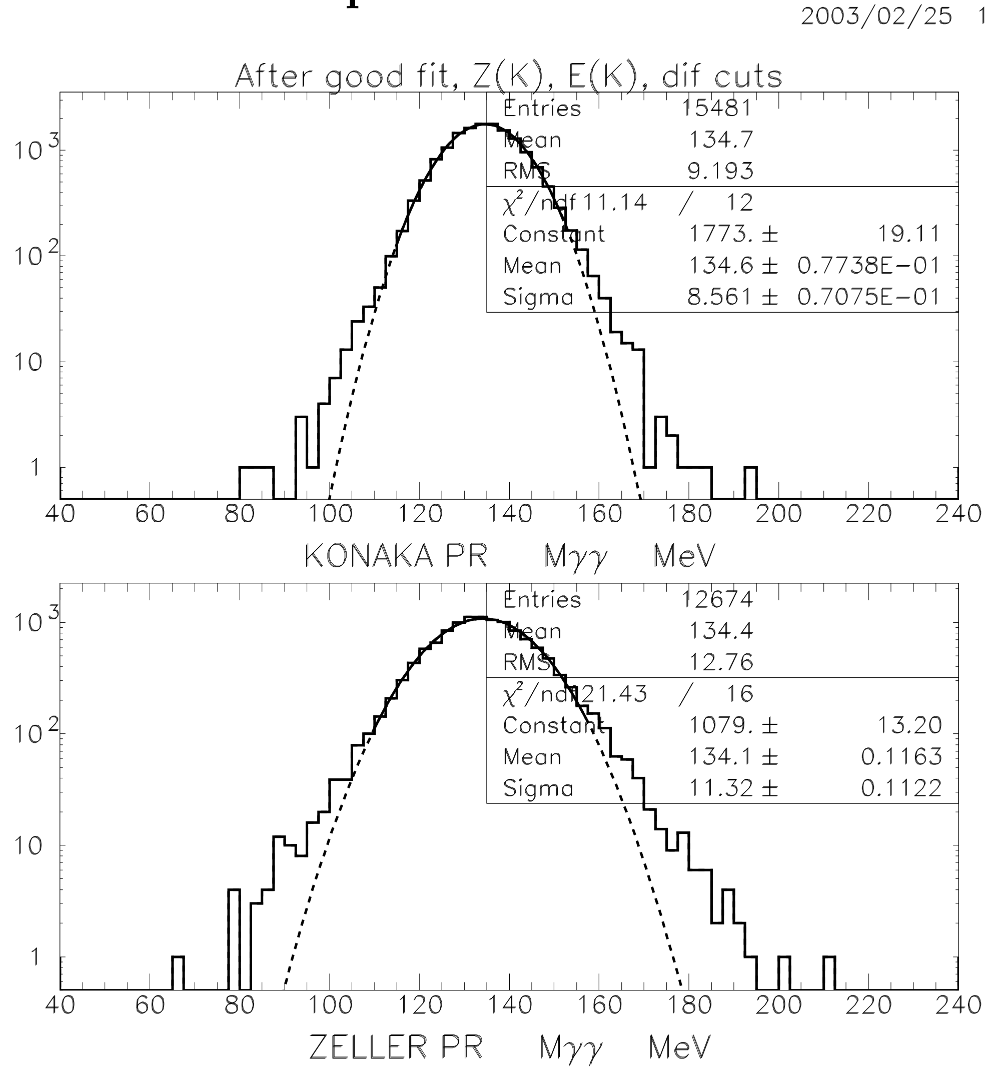
- Only study acceptance for **both** γs converting in PR
- Cuts used for comparison were optimized for the 100×5 mrad^2 geometry with clearance 22.5 cm $\times$ 6.625 cm. (For this study, 100×5 mrad^2 has clearance 25.6 cm $\times$ 5.36 cm.)
- Major K^0_L backgrounds only: $3\pi^0$, $2\pi^0$, $\pi^+\pi^-\pi^0$ and $\pi e \nu \gamma$
- Photons that pass through the beam hole aperture and traverse the PR are included.
- Both Konaka and Zeller simulations of the PR were tried.

Konaka PR: Use double gaussian to simulate PR angular resolution.

Zeller PR:

```
A program to  reconstruct the response of analog strip
pre-radiator for E926.  The basic geometry is 2 nested
hexagonal tubes with readout between, separated by Pb
radiator of thickness TPb (cm). ...Takes average of two
analog hits at each plane.  Randomize which comes first,
x or y. This version has mult scat at each tube.
```

Resolution comparison: Konaka and Zeller PR



For signal events, $M(\gamma\gamma)$ resolution is significantly worse for Zeller PR. Core resolutions:

$\sigma(\text{KONAKA}) = 8.56 \pm 0.07\ \text{MeV}/c^2$,

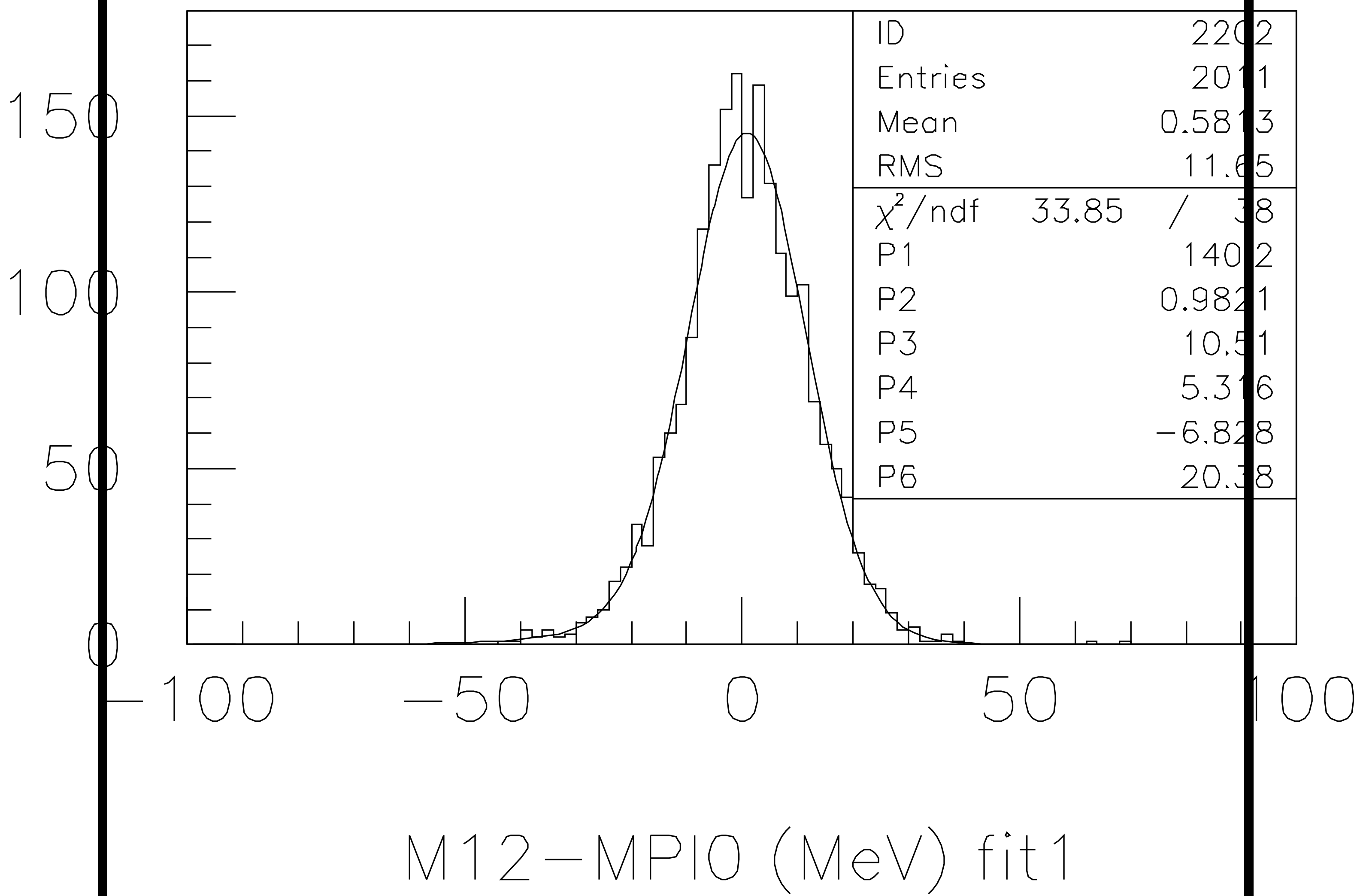
$\sigma(\text{ZELLER}) = 11.32 \pm 0.11\ \text{MeV}/c^2$

$\sigma(\text{GEANT}) = 10.5\ \text{MeV}/c^2$ (next page)

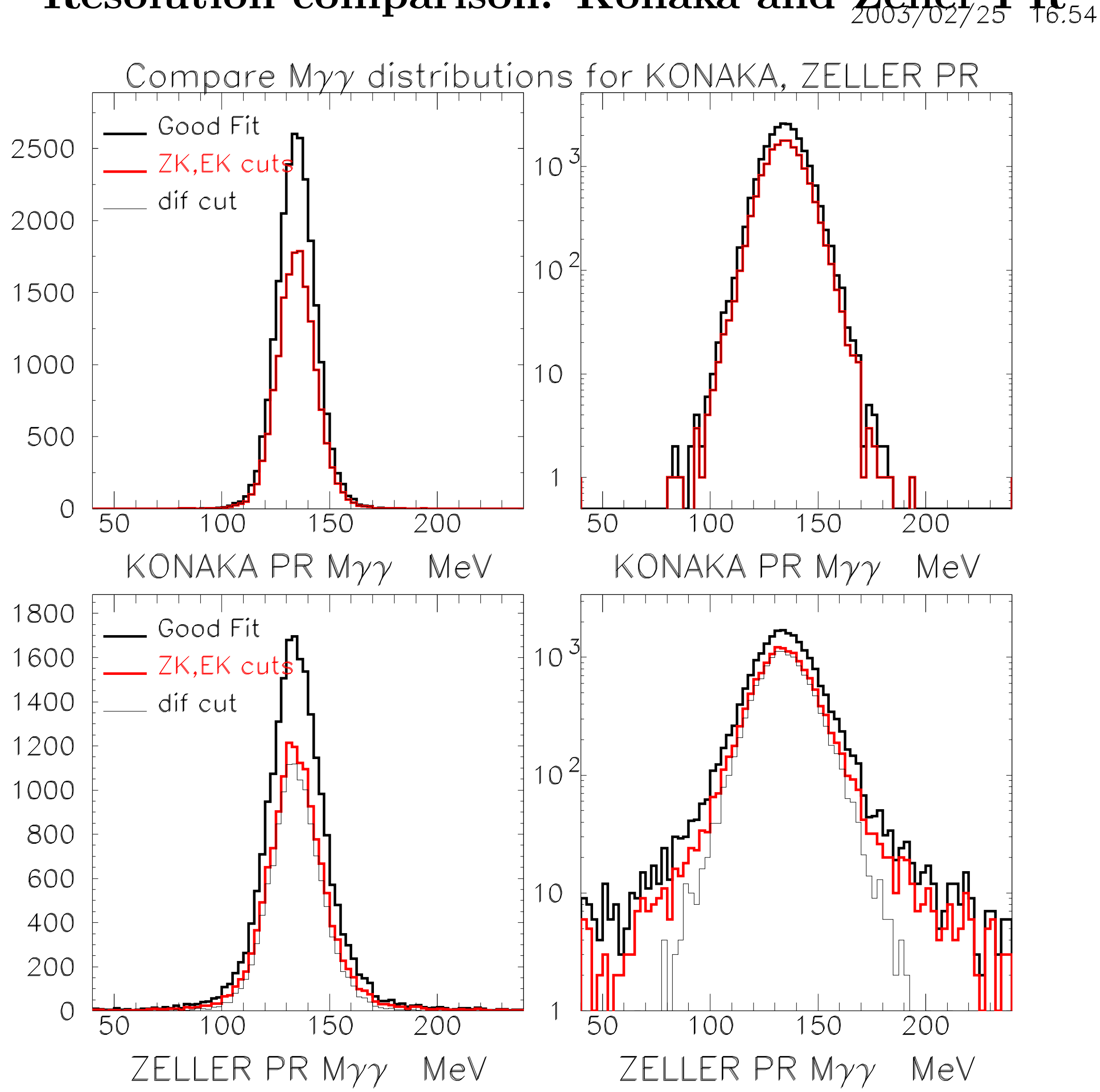
GEANT (true?) core resolution lies in between the two models used in the FastMC.

Resolution comparison: GEANT MC

π^0 events generated at Z=1150 cm, require $\chi^2 < 25$:



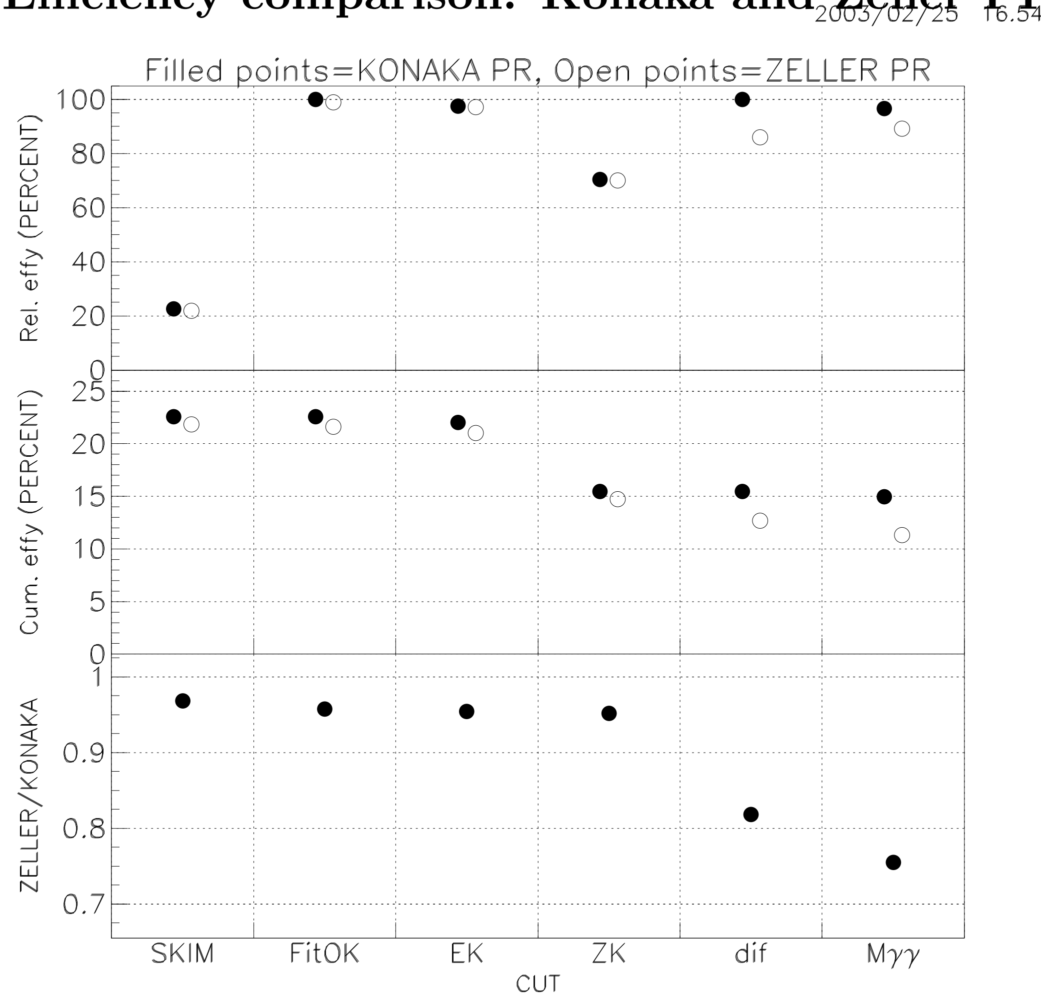
Resolution comparison: Konaka and Zeller PR



For signal events, core resolution on $M(\gamma\gamma)$ is significantly worse for Zeller PR and there are larger tails that can be removed with a cut on δ ("dif cut")

For Zeller PR model, $\delta = \sqrt{\delta_x^2 + \delta_y^2}$ where δ_x, δ_y is the difference in x,y between measured e^- and e^+ positions at last plane used for measurement.

Efficiency comparison: Konaka and Zeller PR



SKIM: see next page

FitOK: no singular matrix

EK: $638 < E(K) < 1486\ MeV$

ZK: $1025 < Z(K) < 1300\ cm$

dif: $\delta < max(1., 4. - 0.005 * E_\gamma(MeV))$ cm

$M(\gamma\gamma)$: $|M(\gamma\gamma) - M(\pi^0)| < 20\ MeV^2|$

For these cuts, effy(Zeller PR) = 75% effy(Konaka PR).

This accounts for the observed yield difference between the two models.

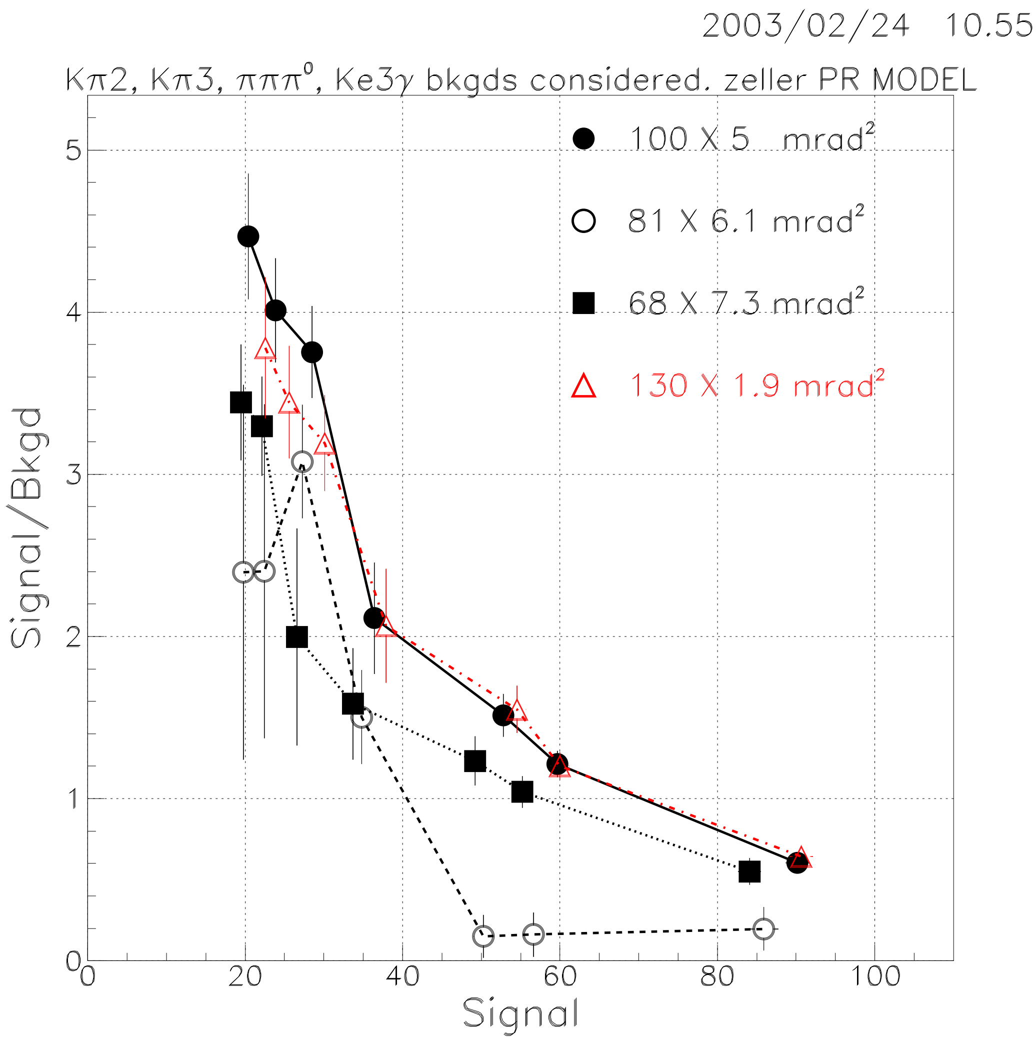
Cut definition info

SKIM CUTS:

- Generated Photon at 10 r.l. into PR/CAL
  $|X| < 300.00, |Y| < 300.00$ cm
- Reconstructed K_L candidate:
  - $0.00 < E(K) < 1486.00$ MeV and
  - $0.00 < Z(K) < 2000.00$ cm
- Reconstructed π^0 candidate:
  - $0.00 < E^*(\pi) < 240.00$ MeV
  - $100.00 < M(\gamma\gamma) < 170.00$ MeV/c^2
  - $E^*(\pi) - |E^*(\gamma 1) - E^*(\gamma 2)| > 0.0$ MeV

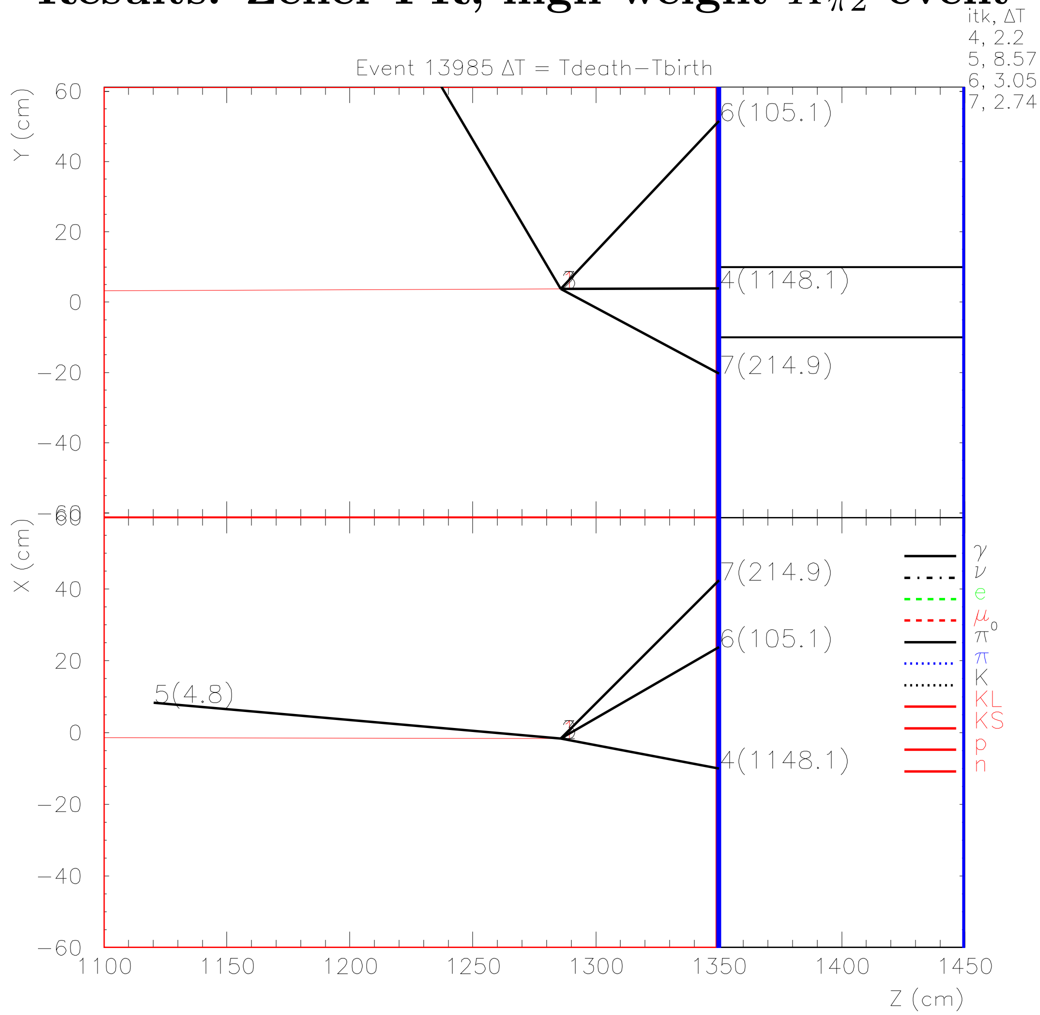
For Zeller PR model, $\delta = \sqrt{\delta_x^2 + \delta_y^2}$ where δ_x, δ_y is the difference in x,y between measured e^- and e^+ positions at last plane used for measurement.

Results: Zeller PR



Background rate for 81×6.1 mrad^2 configuration is dominated by a single, high weight $K_{\pi 2}$ event.

Results: Zeller PR, high weight $K_{\pi 2}$ event



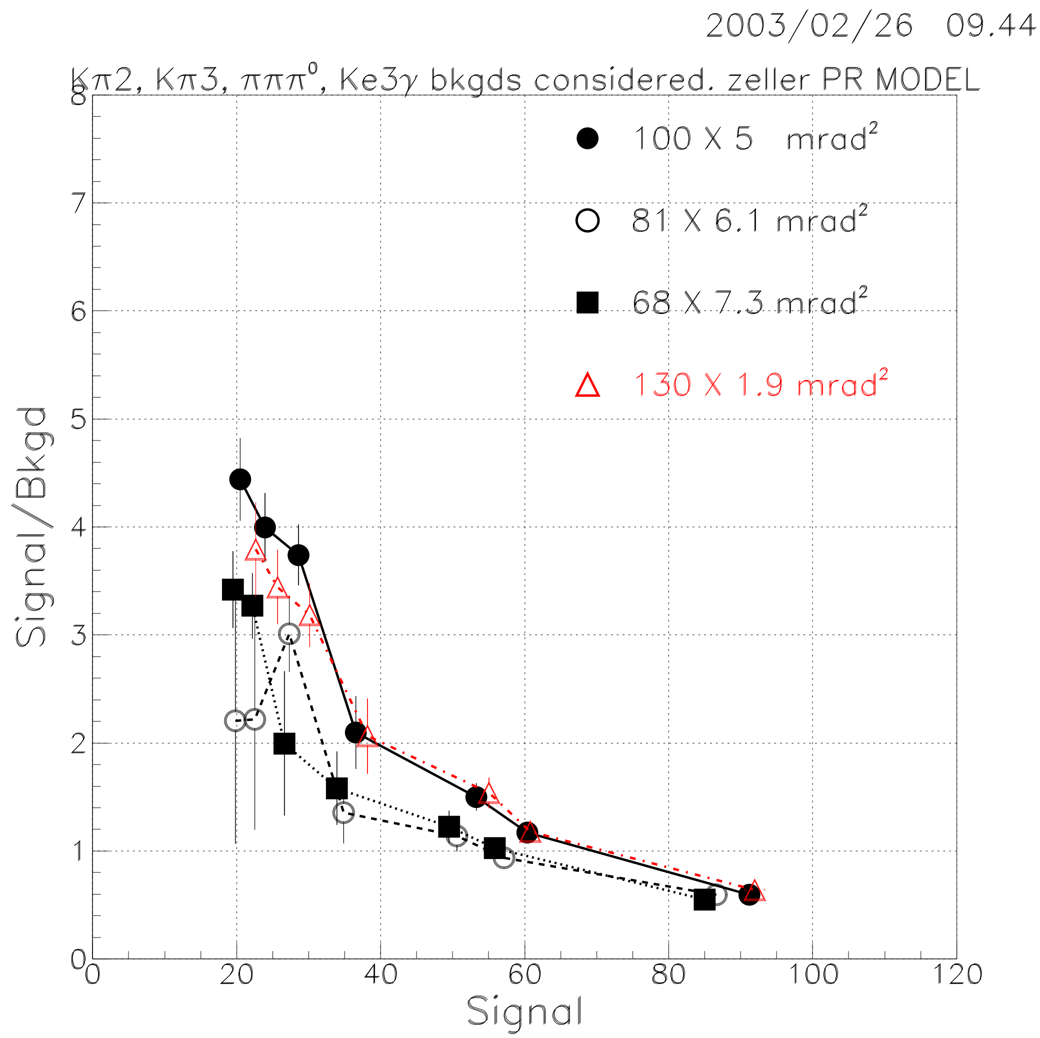
Top: Y *vs* Z, Bottom: X *vs* Z

Thin, red line is incoming K^0_L, outgoing γ are thick black lines.

Tracks 6,7 are the π^0 candidate and are from a π^0 decay. Track 5 goes backward into the BV with 4.8 MeV. Track 4 hits the catcher with 1148.1 MeV.

I exclude the file with this event from further studies.

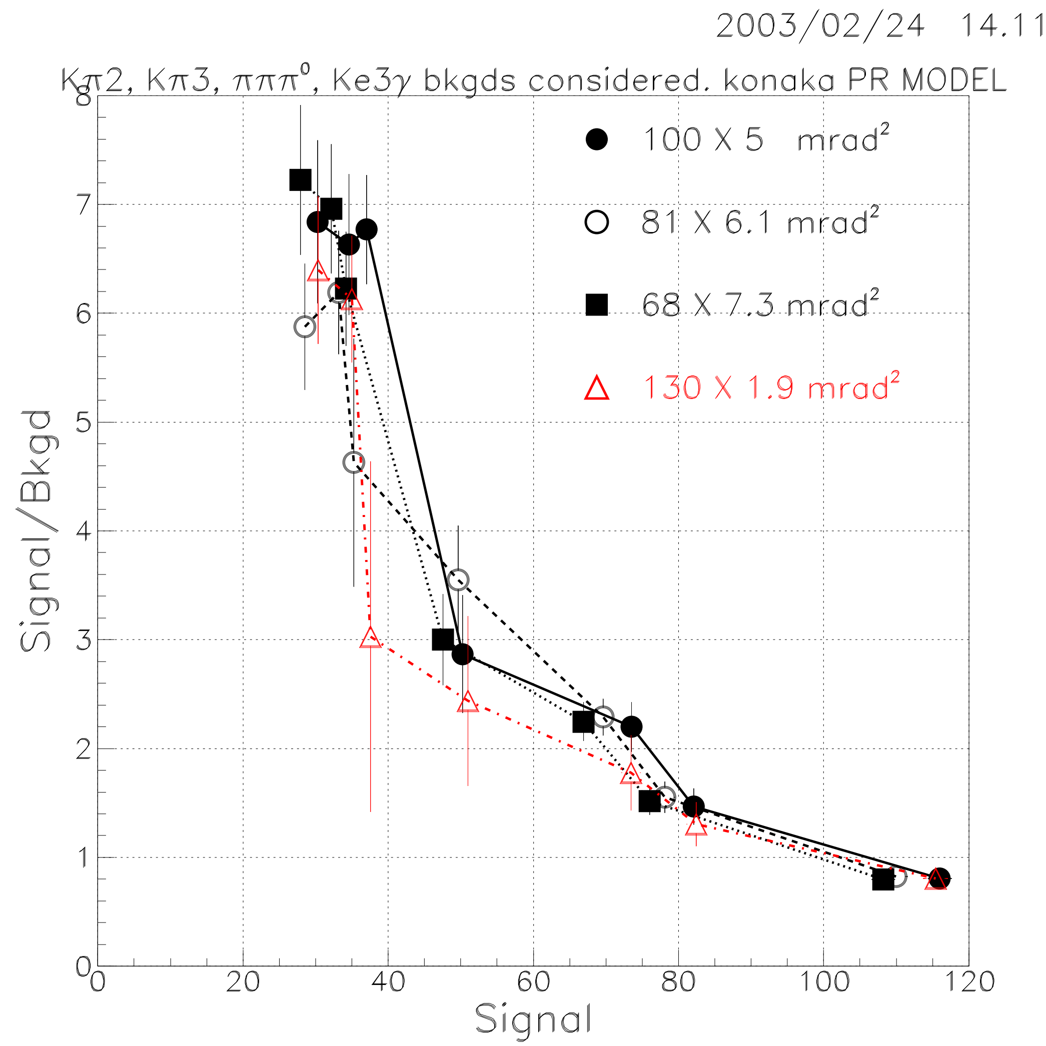
Results: Zeller PR



High weight event removed.

100×5 and 130×1.9 configurations are consistent and have $\sim 1.15\times$ higher S/B than 81×6.1 and 68×7.3 configurations.

Results: Konaka PR

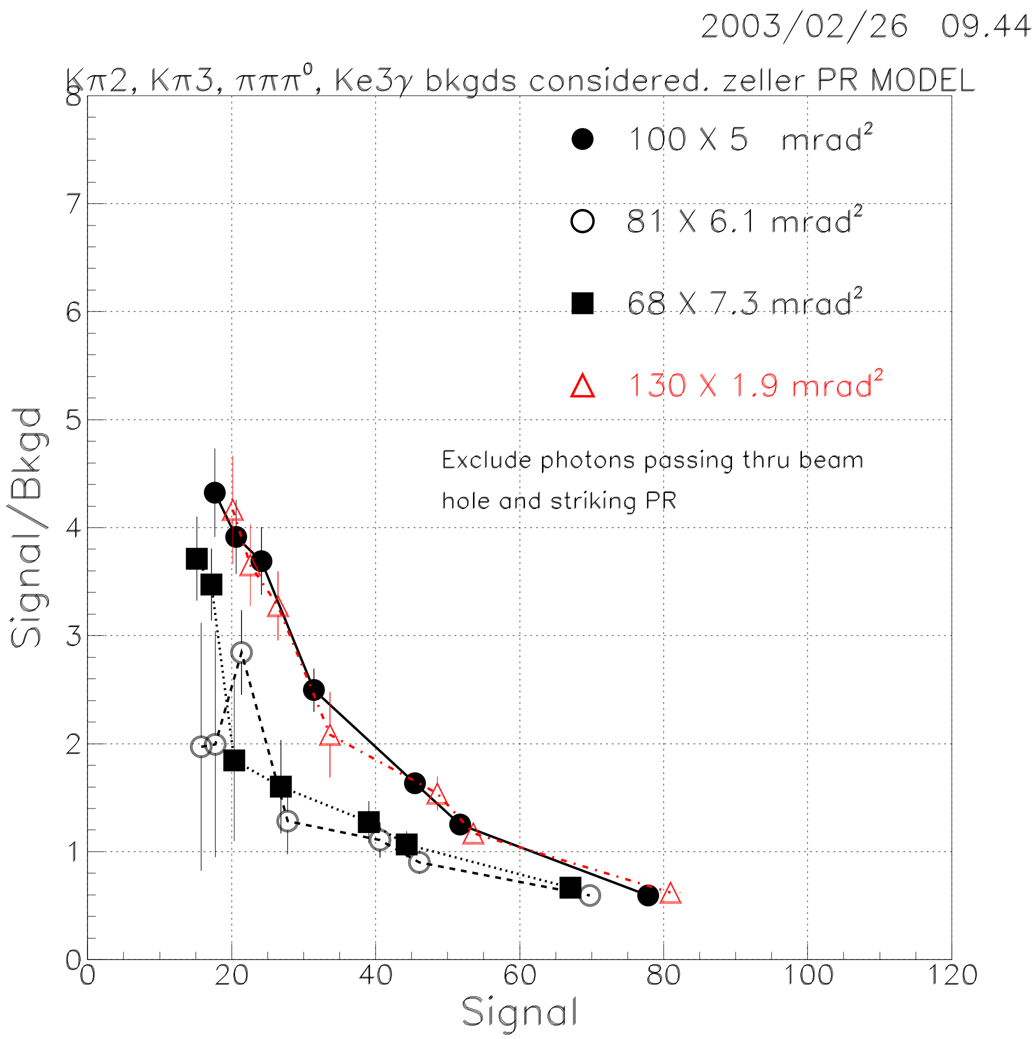


S/B and signal yields significantly higher than for Zeller PR as expected.

All configurations give consistent S/B and signal yields.

Results: Zeller PR, exclude γ thru beam hole

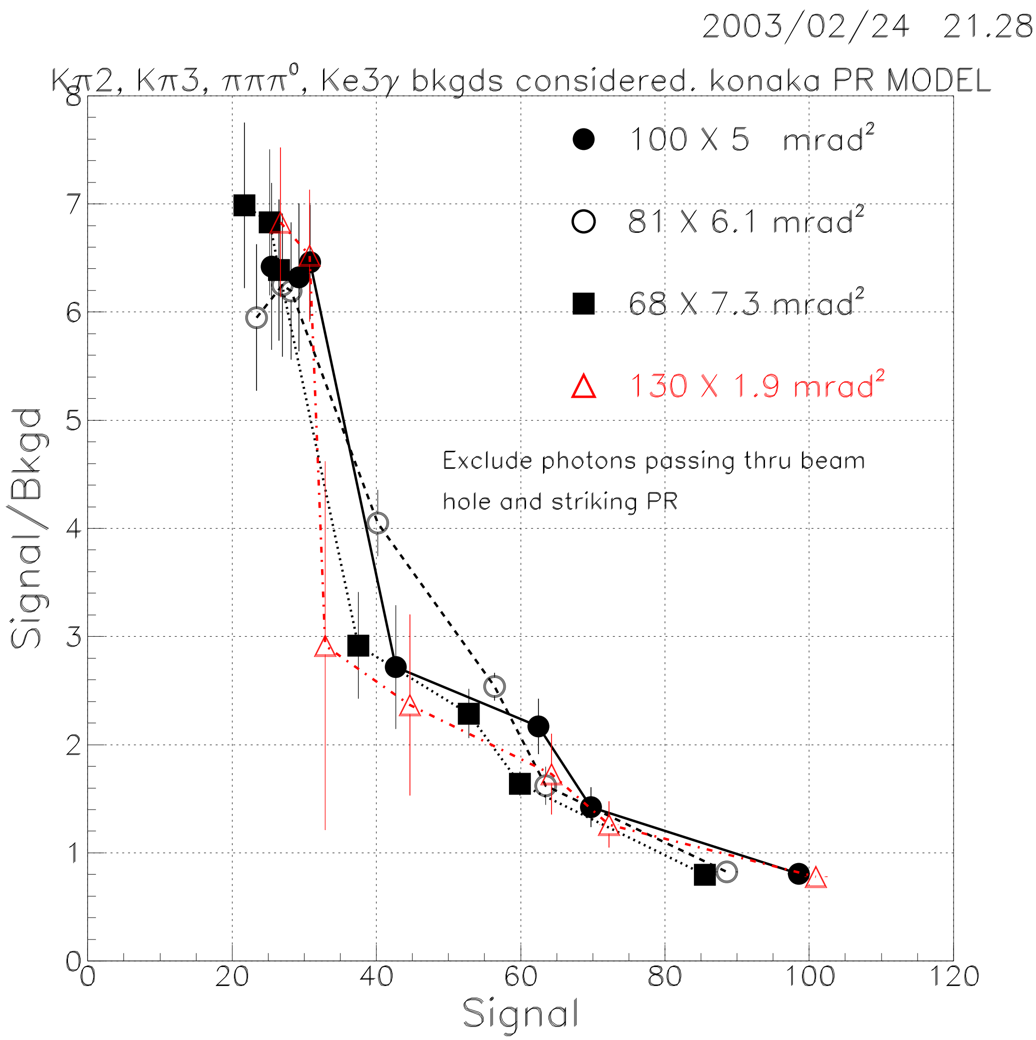
As a test, exclude photons that pass through the beam hole and traverse the PR and recalculate yields.



Result: Uniform decrease of signal yields while maintaining S/B.

Results: Konaka PR, exclude γ thru beam hole

As a test, exclude photons that pass through the beam hole and traverse the PR and recalculate yields.



Result: Uniform decrease of signal yields while maintaining S/B.

Discussion: Reduction of S/B for Zeller PR

Recall:

100×5 and 130×1.9 configurations are consistent and have $\sim 1.15\times$ higher S/B than 81×6.1 and 68×7.3 configurations.

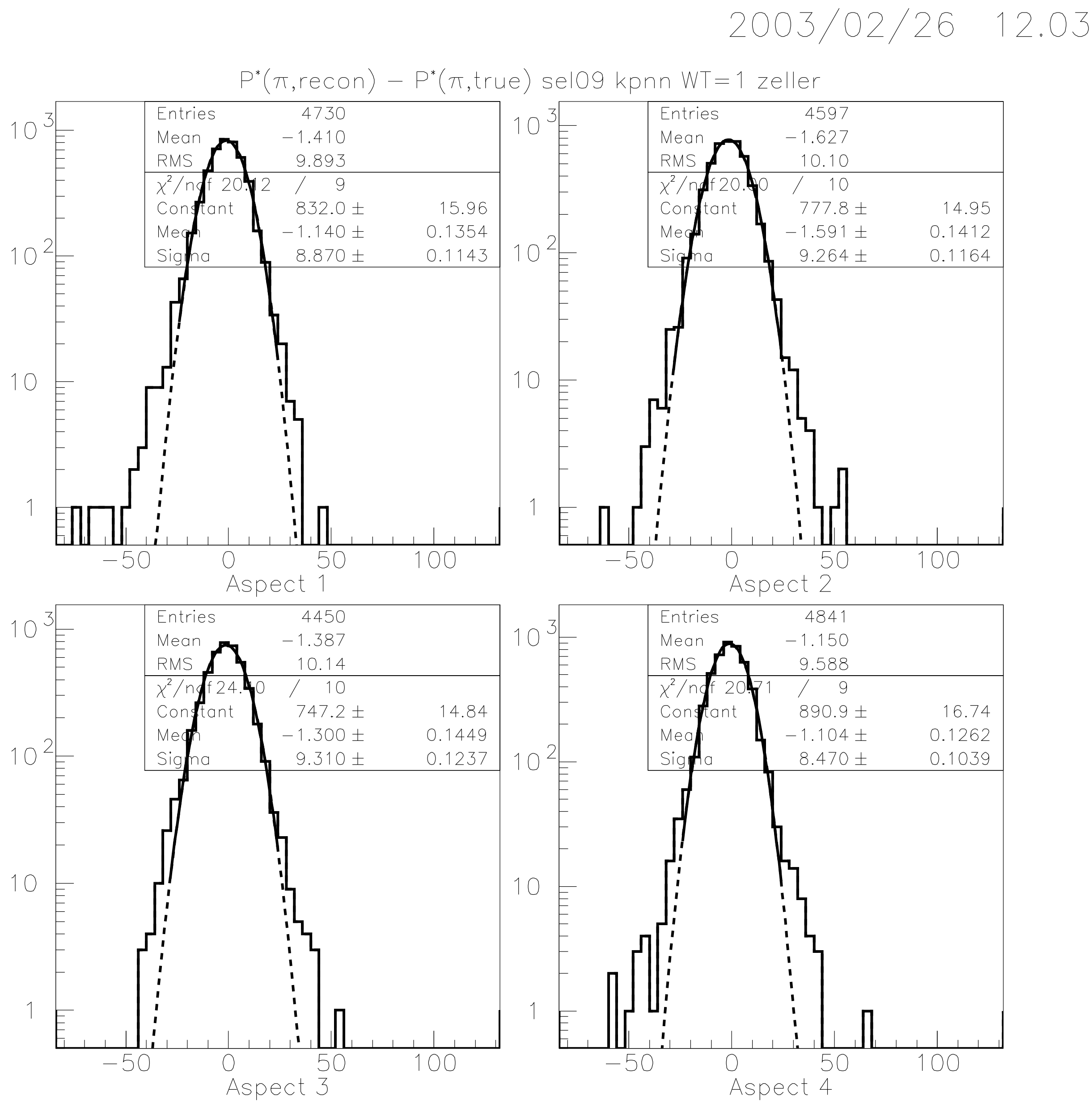
This is close to $\sim 10\%$ statistical precision of this study, nonetheless...

Study of event yields showed that signal yield increased by $\sim 2.5\sigma$, overall background decreased by $\sim 0.5\sigma$ and S/B increased by $\sim 1.25\sigma$ going from 68×7.3 to 100×5 configurations.

Comparisons of distributions for signal decays showed consistency for difference aperture ratios except for resolution on $P^{*}(\pi^{0})$

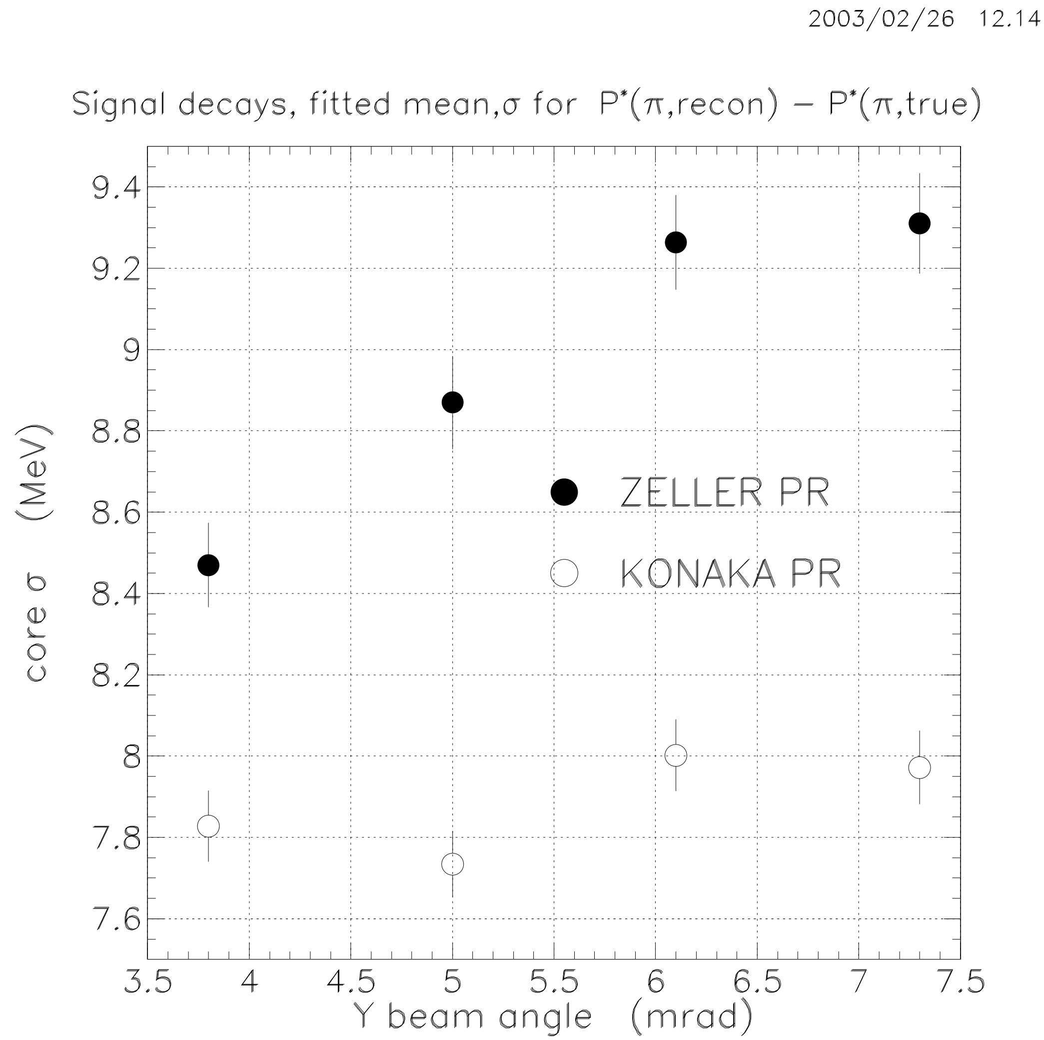
Discussion: $P^*(\pi^0)$ resolution for Zeller PR

Fitted $P^*(\pi^0, \text{recon}) - P^*(\pi^0, \text{true})$ for signal decays.



Discussion: $P^*(\pi^0)$ resolution

Comparison of fitted core resolution of $P^*(\pi^0, \text{recon}) - P^*(\pi^0, \text{true})$ for signal decays.



The core resolution degrades by $\sim 10\%$ for the Zeller PR model as the Y beam angle increases. The degradation, if any, for the Konaka PR model is $\sim 4\times$ less.

I don't have an explanation of this behavior.

Discussion and conclusion

1. All 4 different aspect ratios give consistent S/B and signal yields for the Konaka PR model.
2. Narrower Y beam divergences (100×5 and 130×1.9) had $\sim 1.15\times$ higher S/B than 81×6.1 and 68×7.3 configurations for the Zeller PR model. The difference appears to be due to poorer $P^*(\pi^0)$ resolution.
3. Comparison of $M_{\gamma\gamma}$ resolution of the Zeller and Konaka PR models with GEANT results shows that the fully-simulated PR has a resolution in between the two models.

Therefore there would be a $< 15 \pm 10\%$ difference in S/B and signal yield between the 4 different aspect ratios.