Standalone reconstruction with the AMS RICH detector

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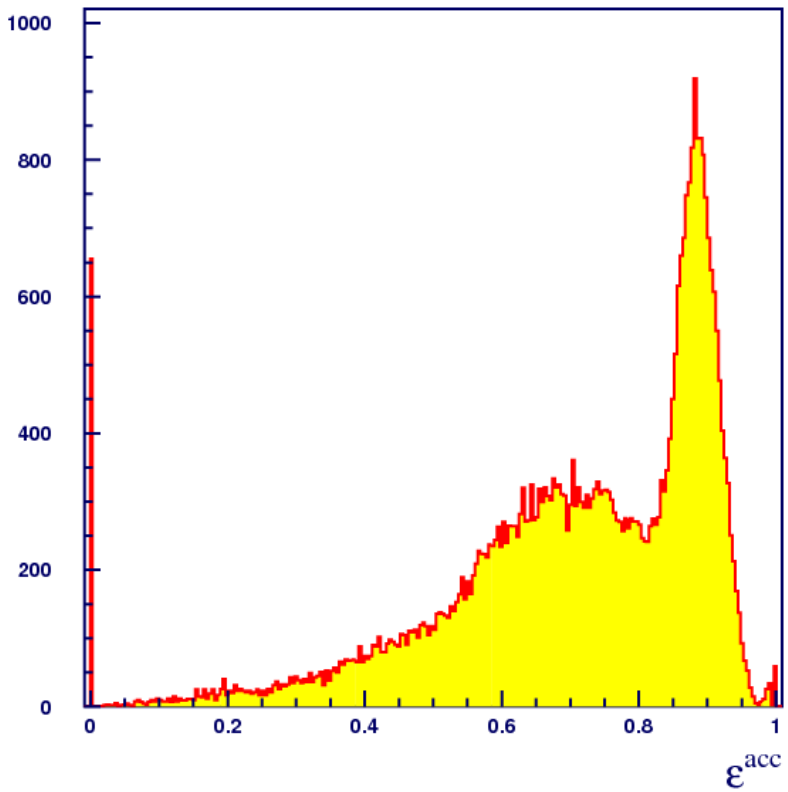
Standalone reconstruction

- Goal: event reconstruction using only data from the RICH detector
  - No track data
- 5 parameters for reconstruction:
  - matrix impact point (x_{matrix}, y_{matrix}), θ, ϕ, θ_c
- Likelihood function used (similar to 1-parameter reconstruction)
- Sample used: proton events in the AMS-02 full simulation with p > 10 GeV/c ($\beta \approx 1$)



visible acceptance for aerogel events with β=1

Reconstruction hint

- PMT matrix crossing point identified by strong signal in matrix (much stronger than ring hits)

- Hint with no track data (unlike Dec. 2006 method):
  - x-y hint given by barycentre of strongest PMT signal
  - Vertical track used as starting point for minimization (in the case of outer impacts a slightly outward track is used to reach the radiator)
  - PMT point must remain within 3 cm of initial hint

- Quality cuts for hint:
  - Quotient between strongest and average PMT signal must be higher than 3 and lower than 10
  - Strongest signal must be higher than 6 p.e.

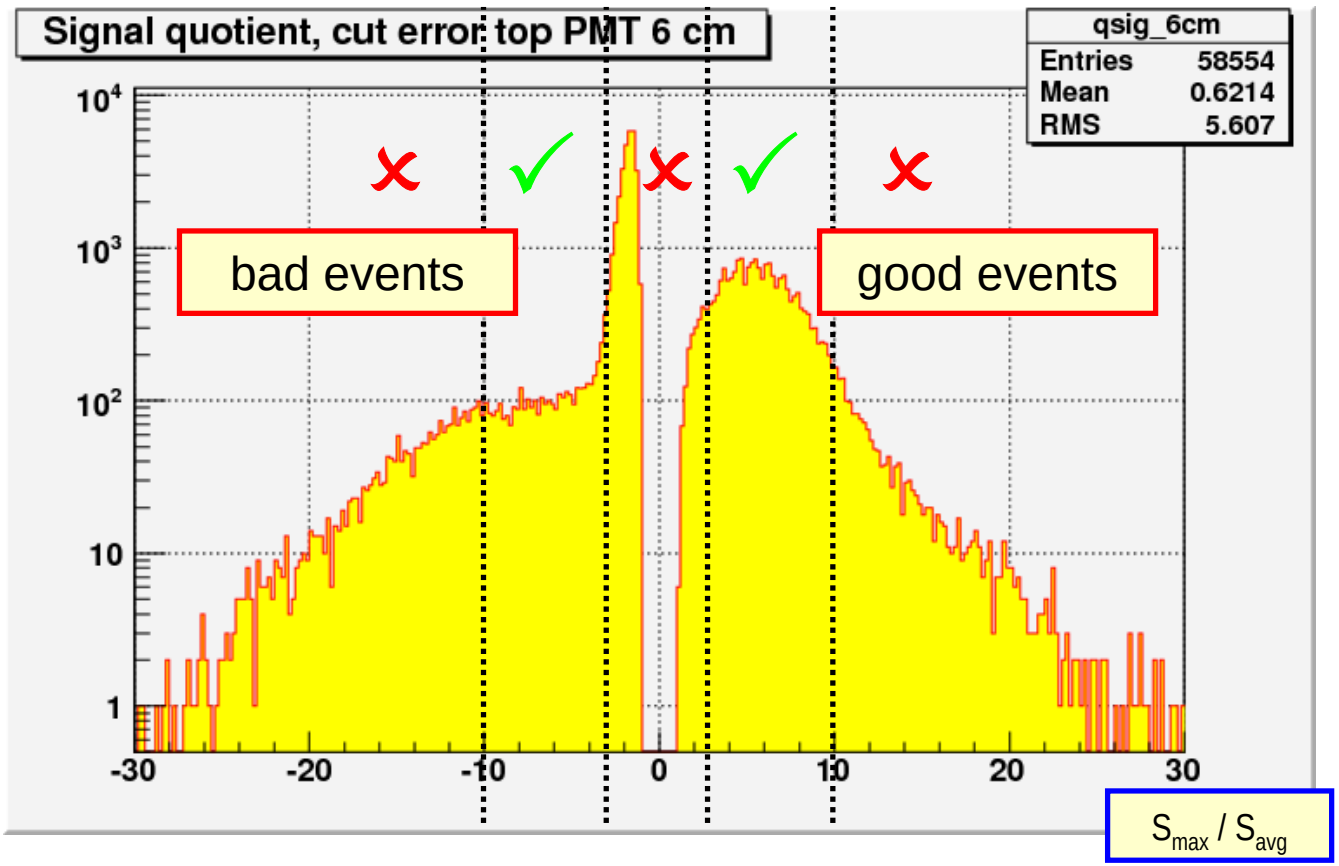
Quality cuts: signal quotient

- $3 < S_{max} / S_{avg} < 10$
  - S_{max} = highest total signal in a PMT
  - S_{avg} = average signal in PMTs hit

Excludes

19% of good events

89% of bad events



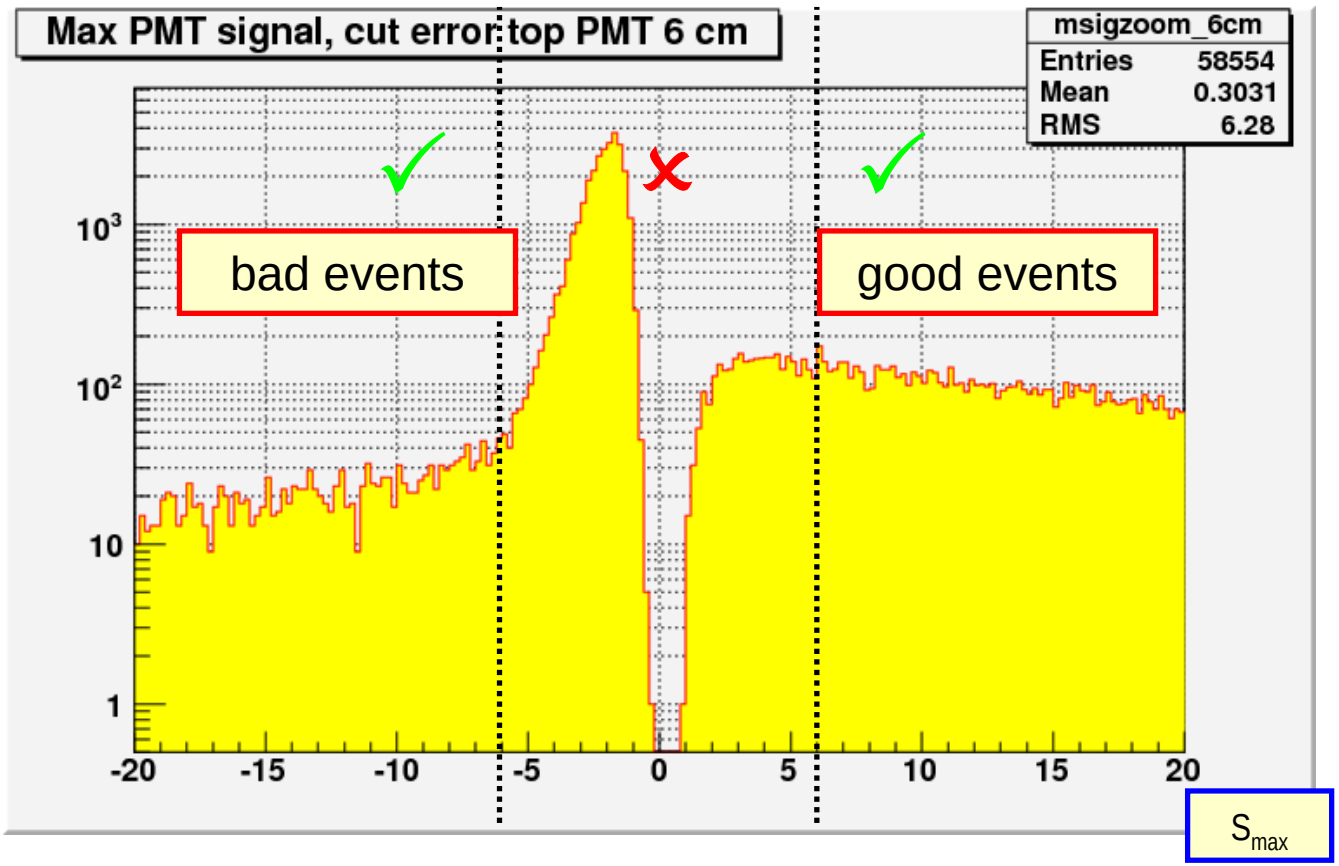
good events defined as having hint < 6 cm from real crossing point

Quality cuts: strongest PMT signal

- S_{max} > 6 p.e.
  - S_{max} = highest total signal in a PMT

Excludes
12% of good events
84% of bad events

2 cuts exclude
22% of good events
91% of bad events



good events defined as having hint < 6 cm from real crossing point

Quality cuts: noisy hits

- Events with >4 noisy hits (non-ring, non-particle) are excluded

Excludes

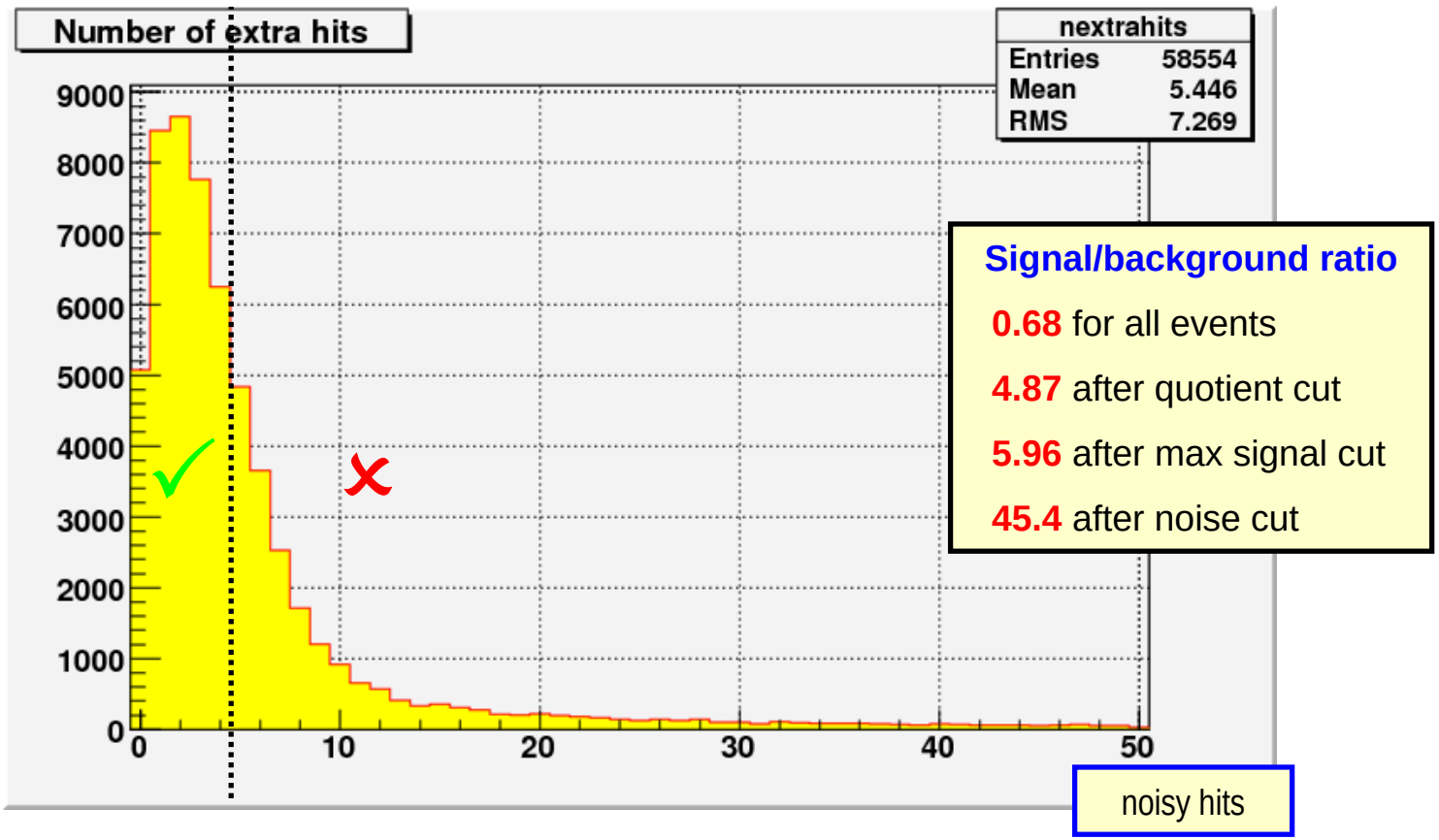
18% of good events

52% of bad events

3 cuts exclude

33% of good events

99% of bad events



Signal/background ratio

0.68 for all events

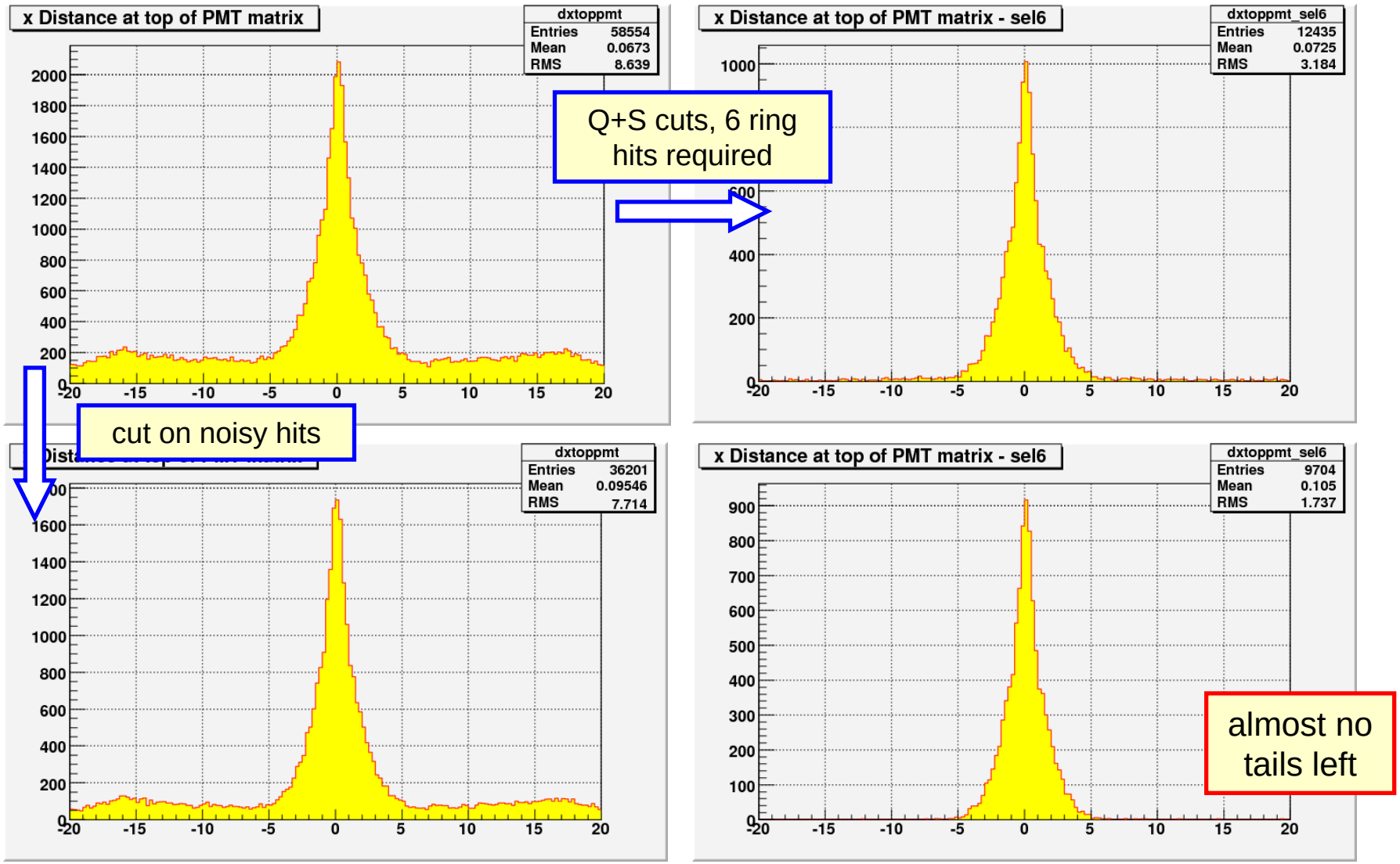
4.87 after quotient cut

5.96 after max signal cut

45.4 after noise cut

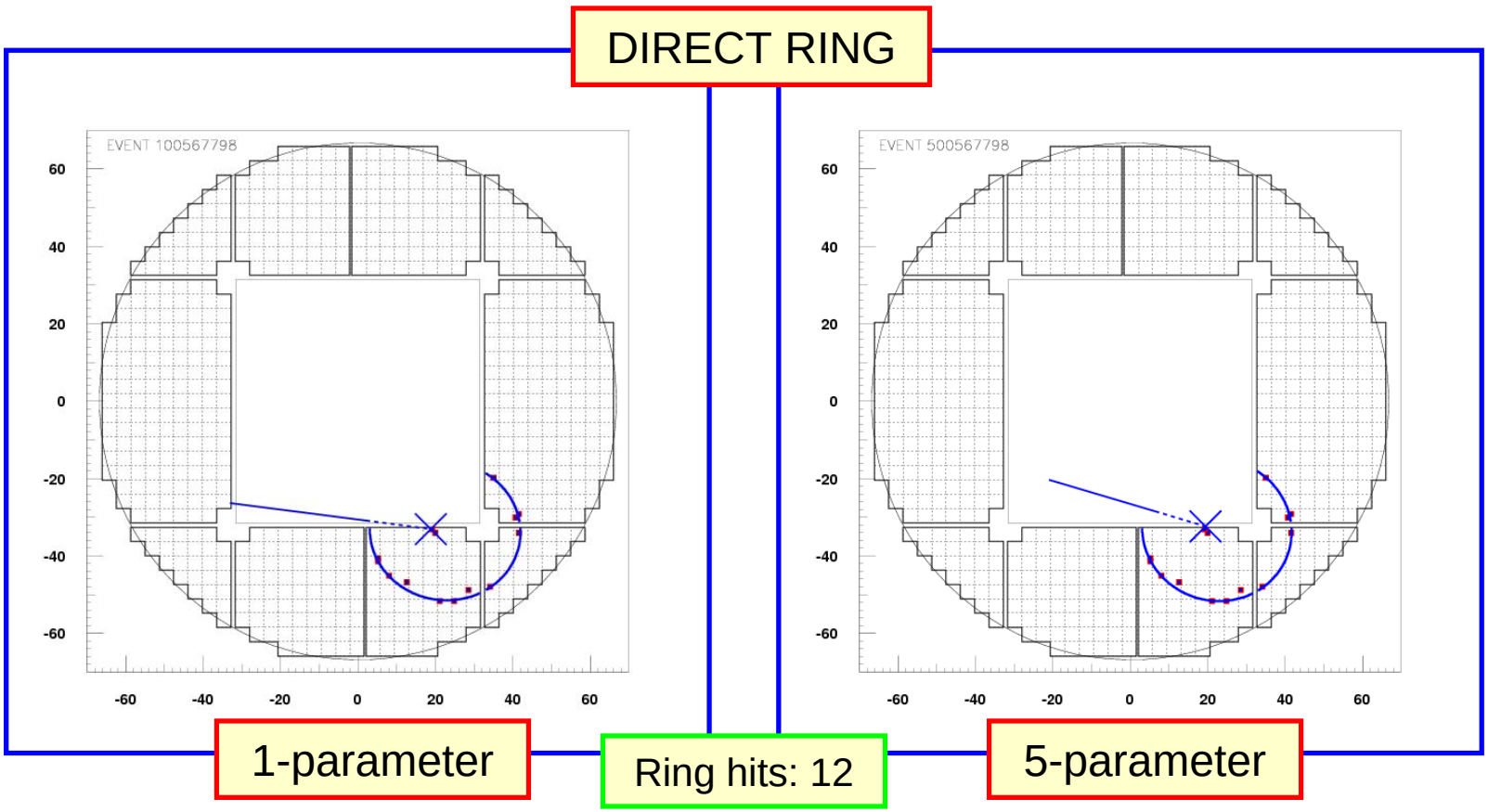
good events defined as having hint < 6 cm from real crossing point

Error in PMT hint (x coordinate)



5-parameter reconstruction examples

- Same event reconstructed with track data (1-parameter) and in the standalone mode (5-parameter):



5-parameter reconstruction examples

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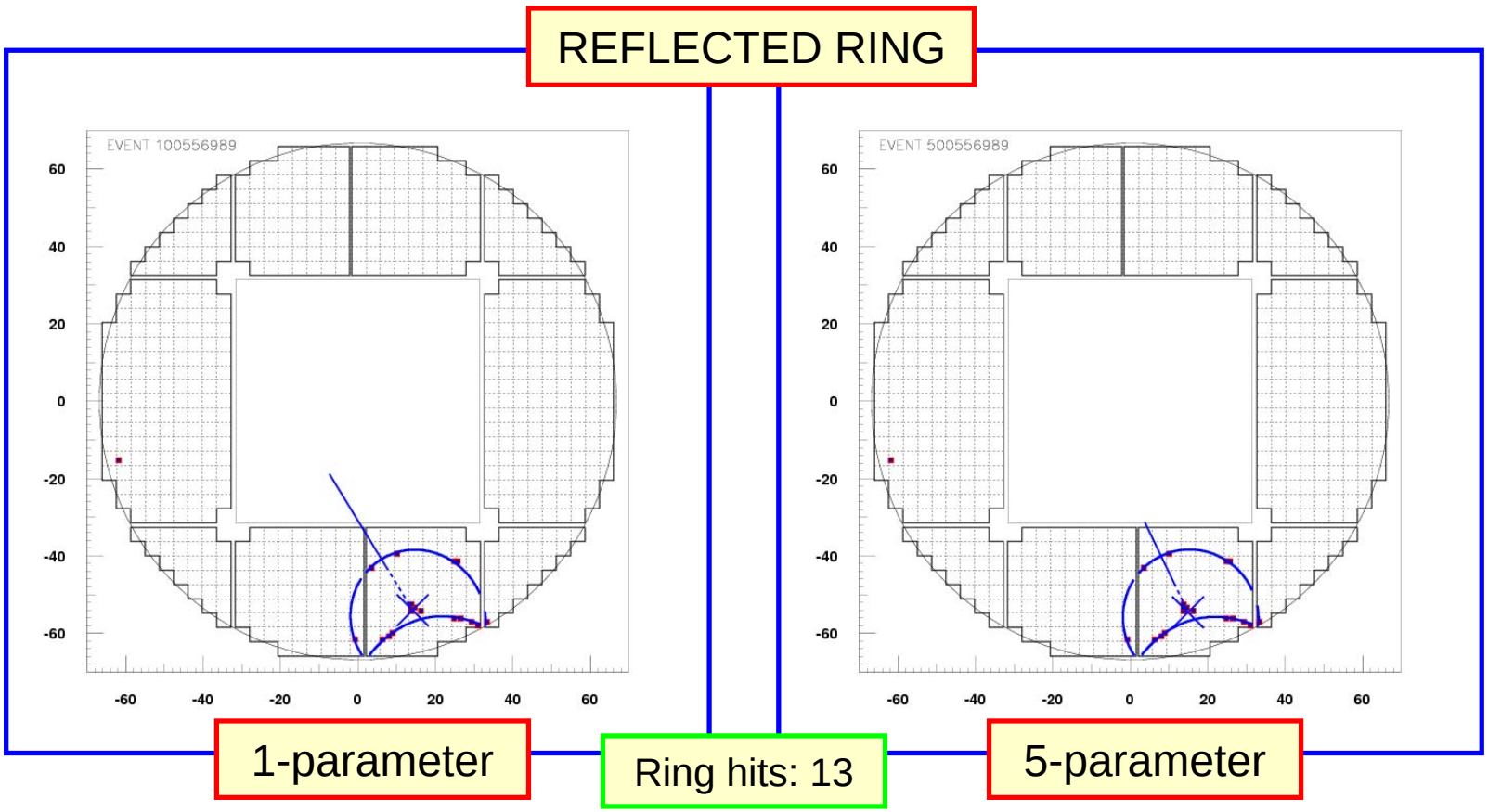
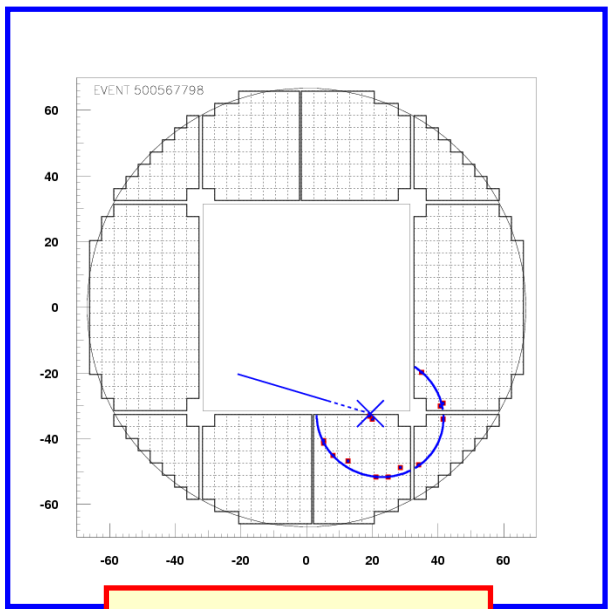
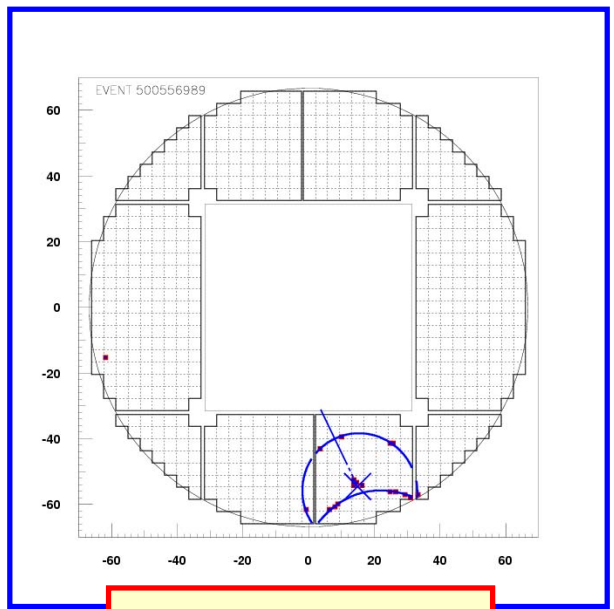


Types of events

- Reconstruction quality studied for three samples (after applying quality cuts):
  - All events
  - Direct events (r_{hint} < 42 cm)
  - Mirror events (r_{hint} > 55 cm)

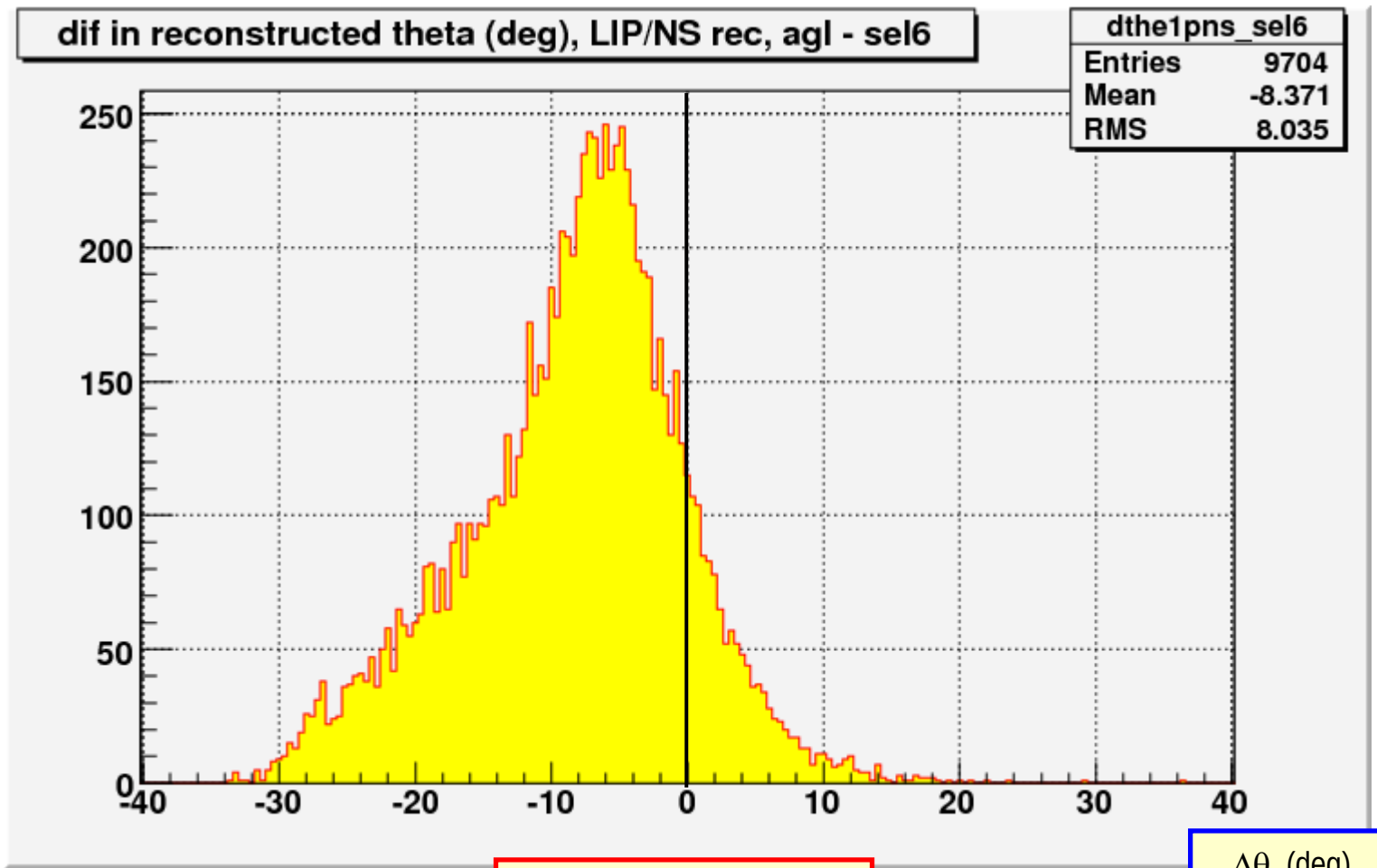


direct event



mirror event

Reconstruction quality: θ

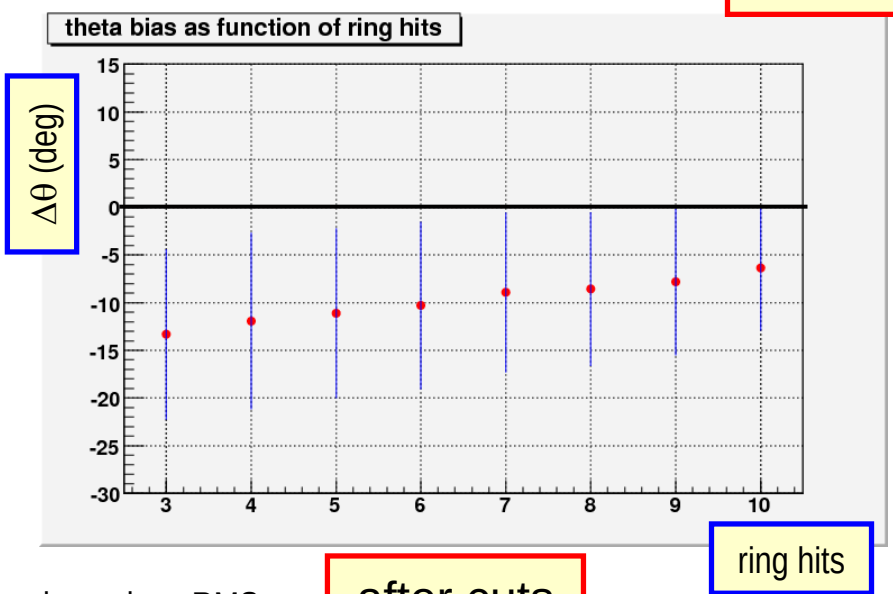


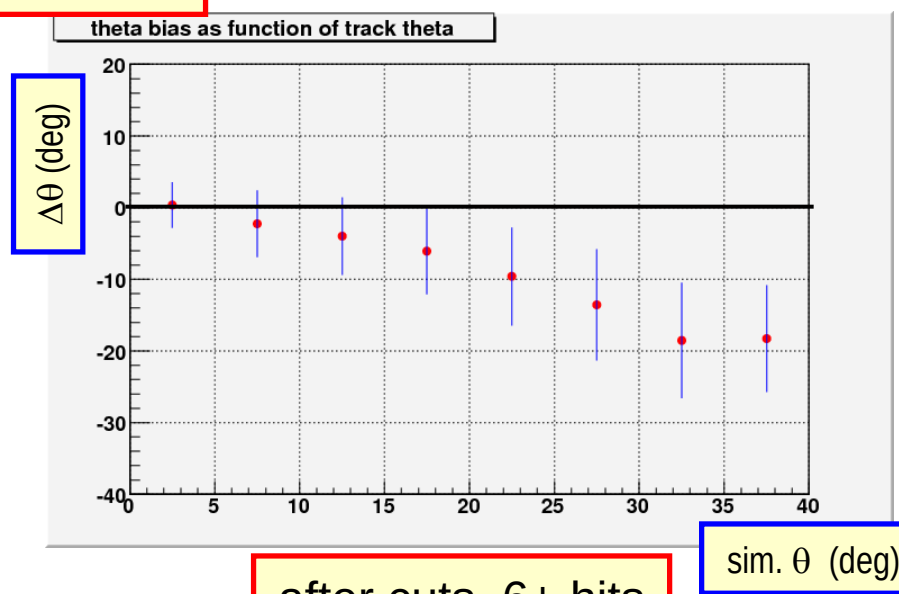
after cuts, 6+ hits

Reconstruction quality: θ, all events

- Strong bias in θ reconstruction
  - Bias increases with θ, spread also increases
  - Reconstructed θ is, on average, about half of simulated angle
  - Bias is smaller for events with higher number of hits
    - Still, $\Delta\theta \sim 7°$ for events with 10 or more hits

ALL EVENTS





after cuts

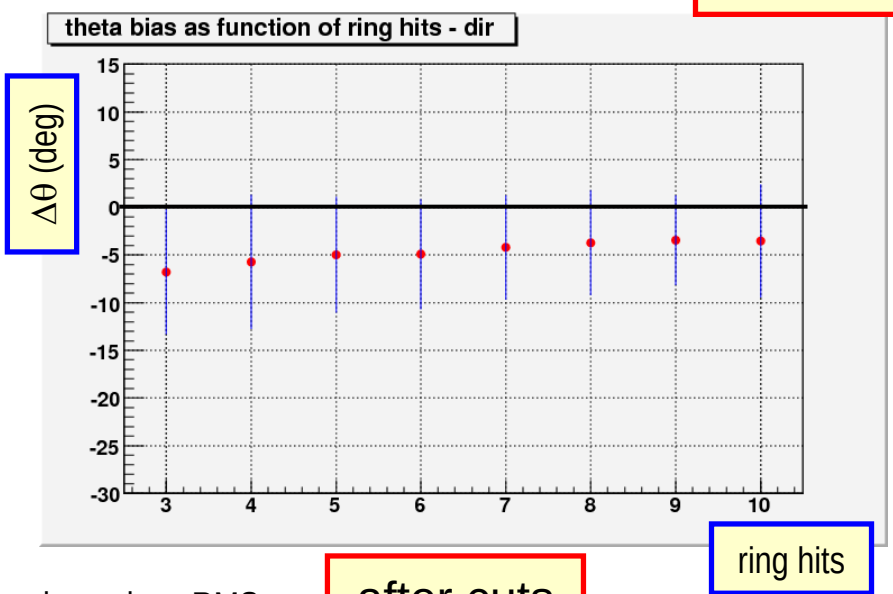
after cuts, 6+ hits

bars show RMS of distributions

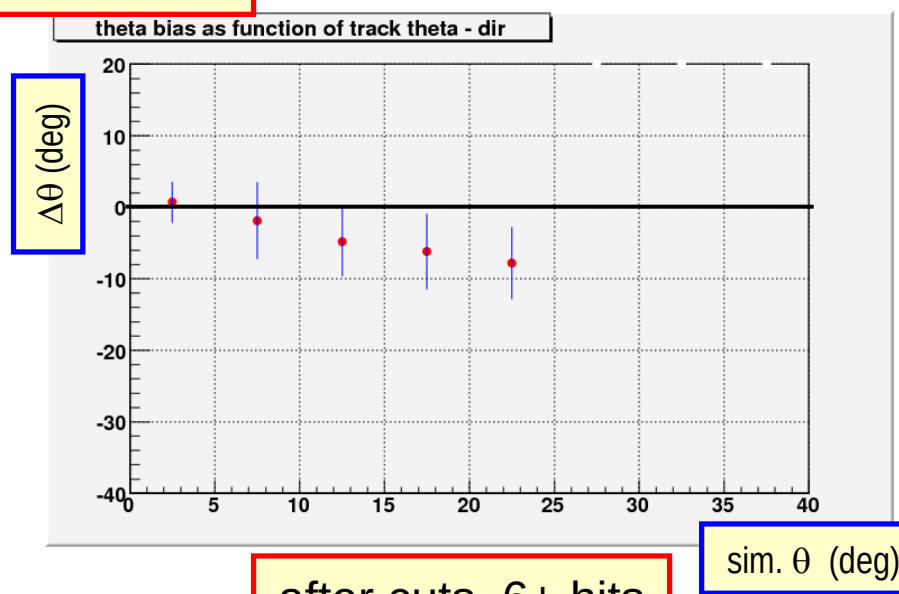
Reconstruction quality: θ, direct events

- Direct events (r_{hint} < 42 cm):
  - Smaller bias, about 4° for events with 7 or more hits
  - Distribution as function of simulated θ shows that reduction in bias is due to smaller average θ: bias is similar for events with same angle

DIRECT EVENTS



after cuts



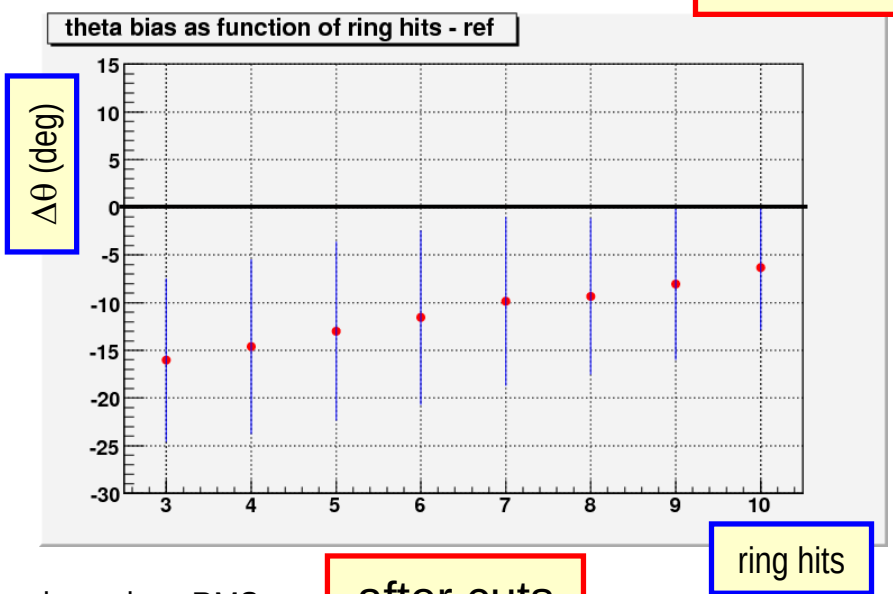
after cuts, 6+ hits

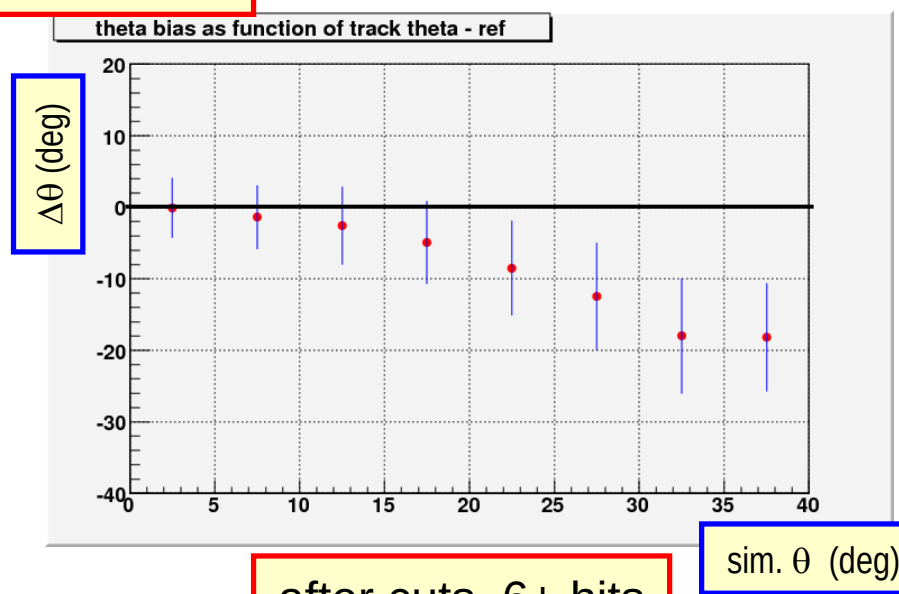
bars show RMS of distributions

Reconstruction quality: θ, mirror events

- Mirror events (r_{hint} > 55 cm):
  - Larger bias due to larger average θ
  - Most events with a high number of hits come from this region due to their high acceptance
  - Again, similar bias for events with same angle

MIRROR EVENTS



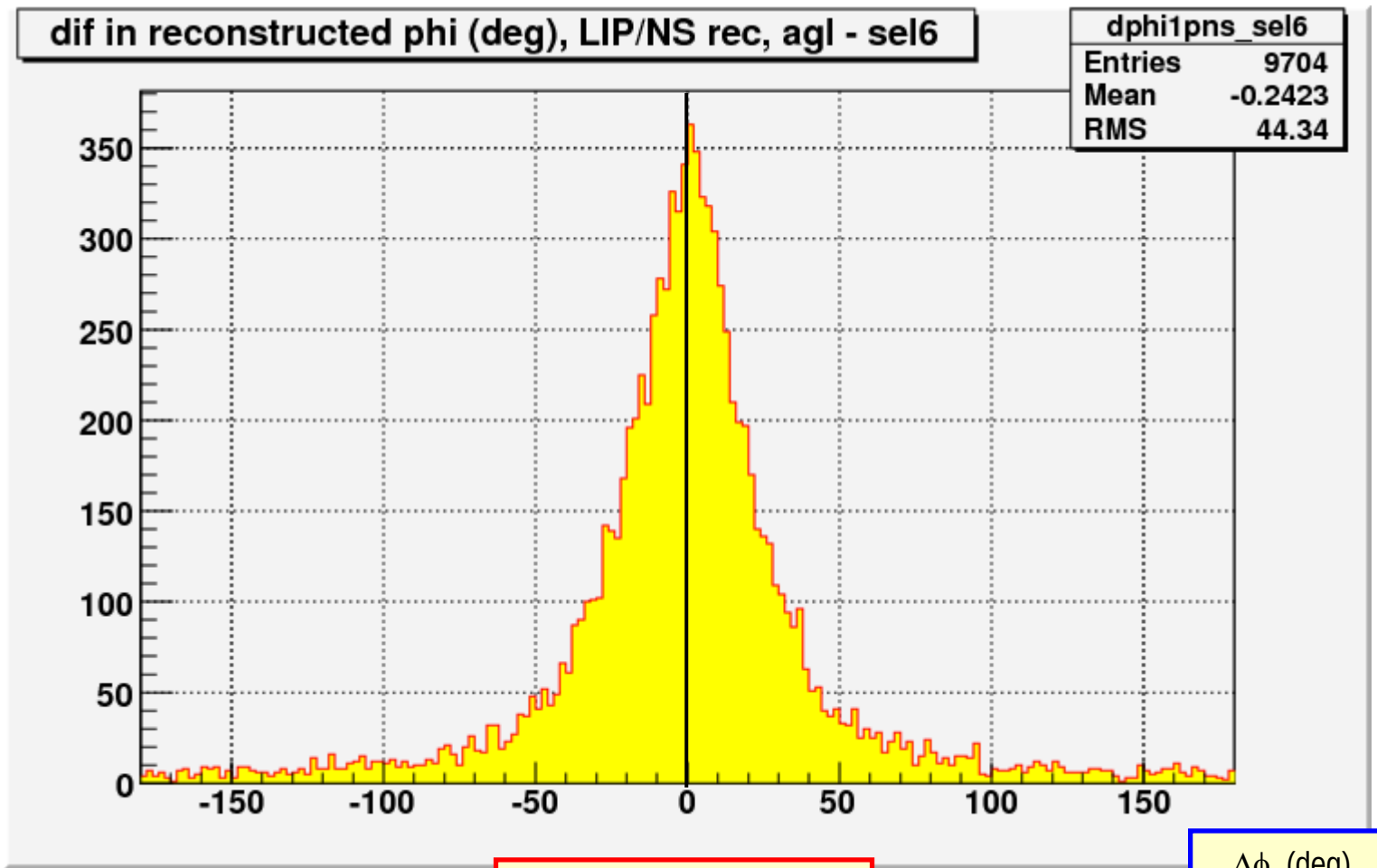


after cuts

after cuts, 6+ hits

bars show RMS of distributions

Reconstruction quality: ϕ

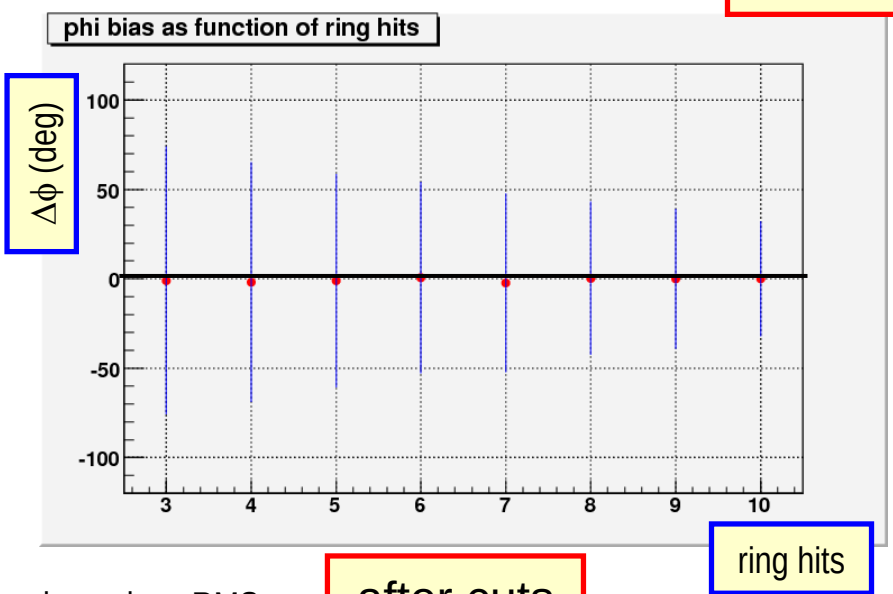


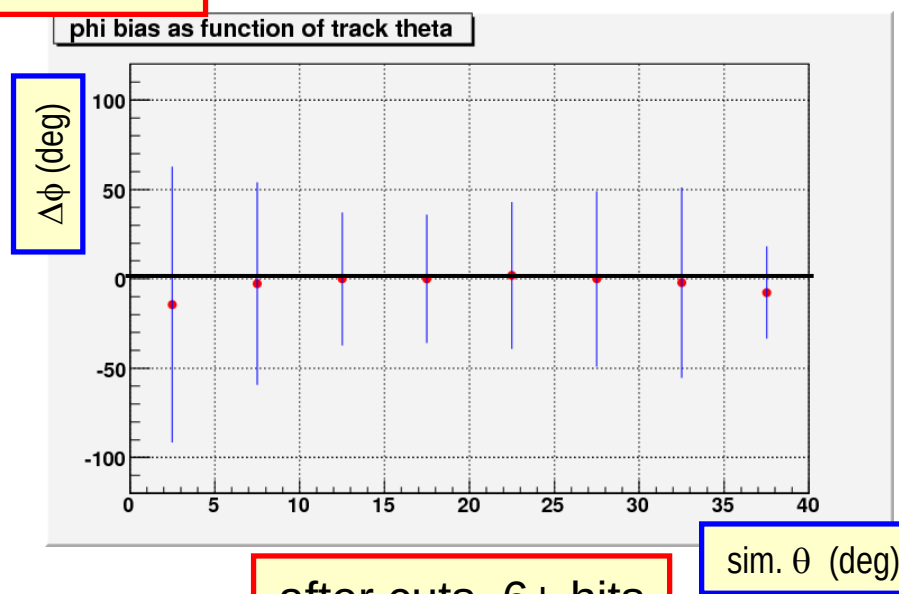
after cuts, 6+ hits

Reconstruction quality: ϕ, all events

- No bias in ϕ reconstruction
  - Spread decreases as number of hits increases
  - Mixed behaviour of ϕ spread as function of θ: decrease in 0°-15° region due to reduction in peak width followed by increase in 20°-35° region due to increase of tails (point for 35°-40° has very low statistics)

ALL EVENTS





after cuts

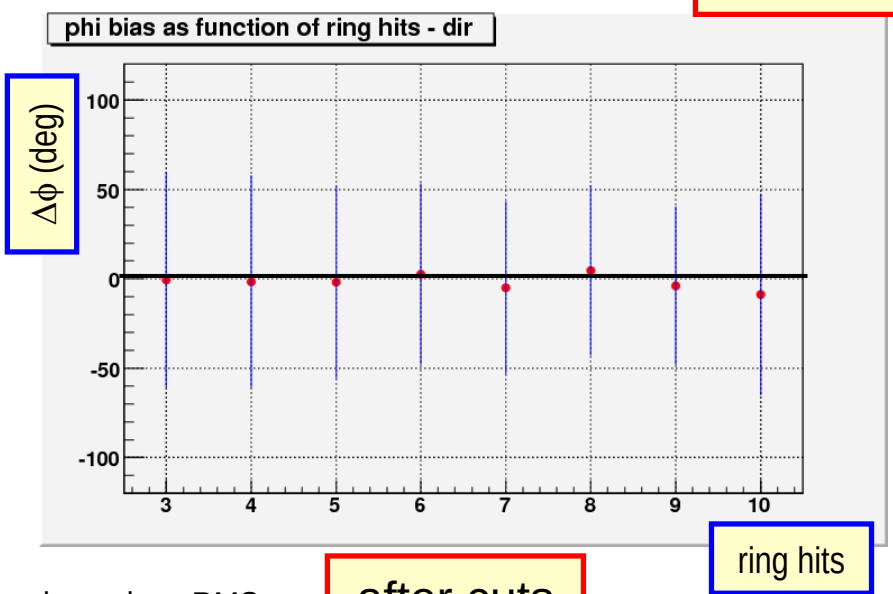
after cuts, 6+ hits

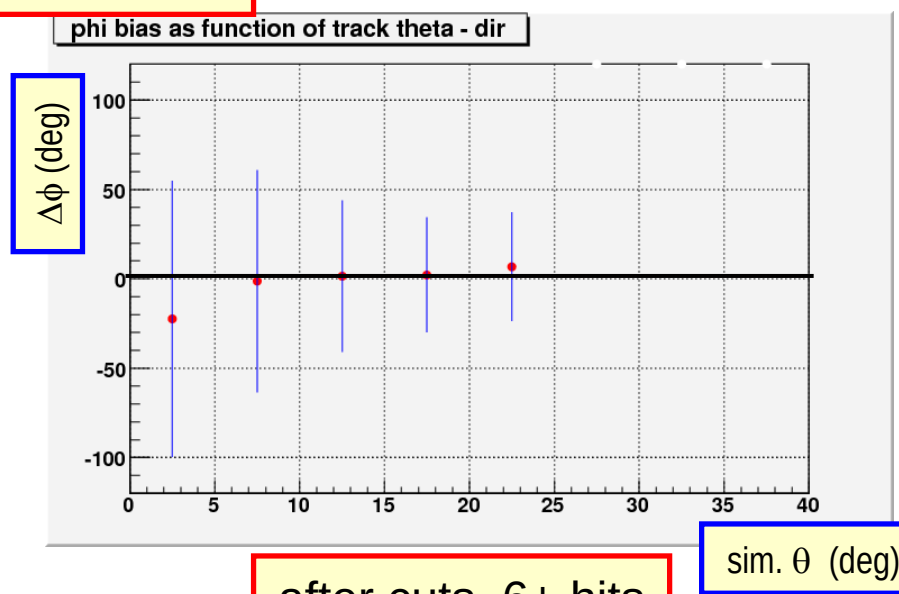
bars show RMS of distributions

Reconstruction quality: ϕ, direct events

- Direct events (r_{hint} < 42 cm):
  - Spread ~50° is almost independent of number of hits
  - ϕ spread decreases to ~30° for θ ~ 20° (no data available for higher θ in this region)

DIRECT EVENTS





after cuts

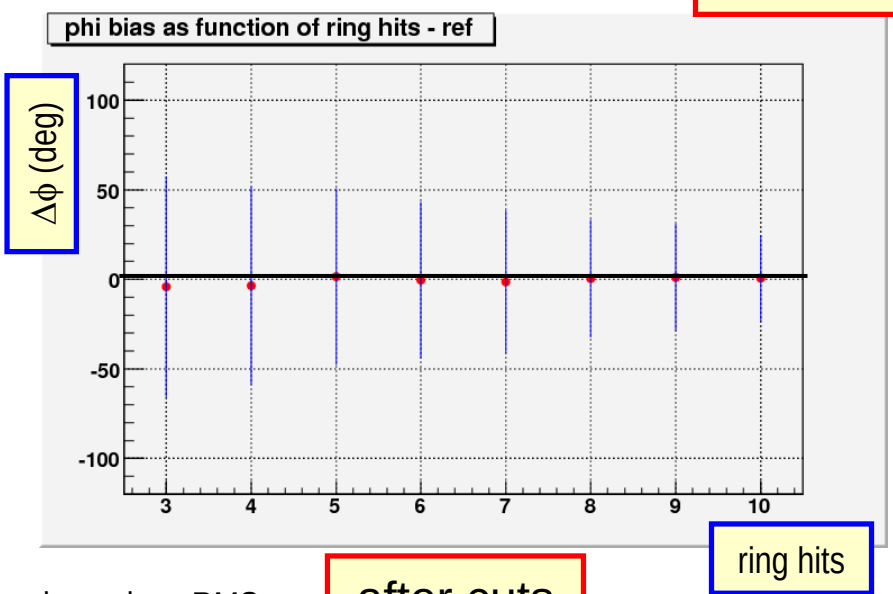
after cuts, 6+ hits

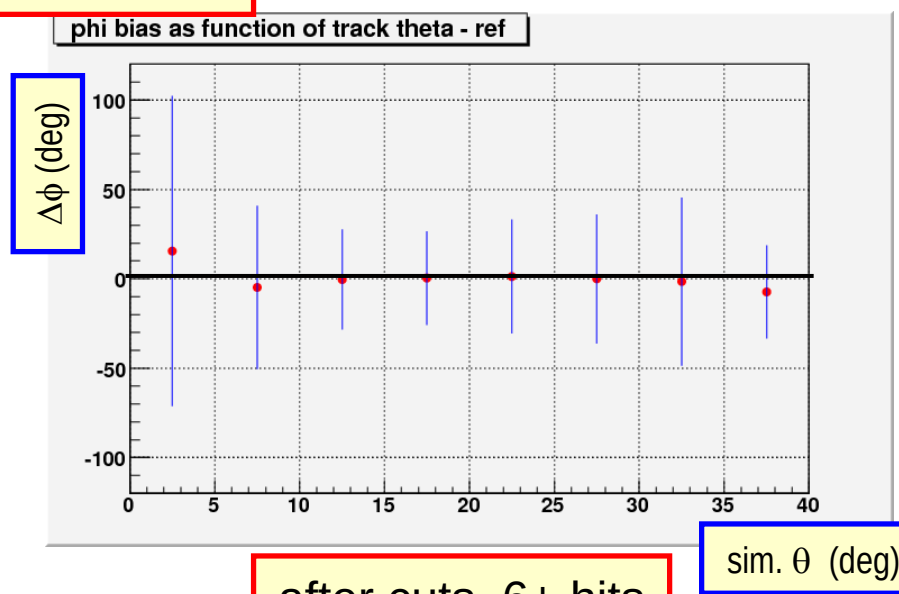
bars show RMS of distributions

Reconstruction quality: ϕ, mirror events

- Mirror events (r_{hint} > 55 cm):
  - Strong decrease in spread as number of hits increases
  - Mixed behaviour of ϕ spread as function of θ: increase in ϕ tails could be due to confusion between direct and reflected branches

MIRROR EVENTS



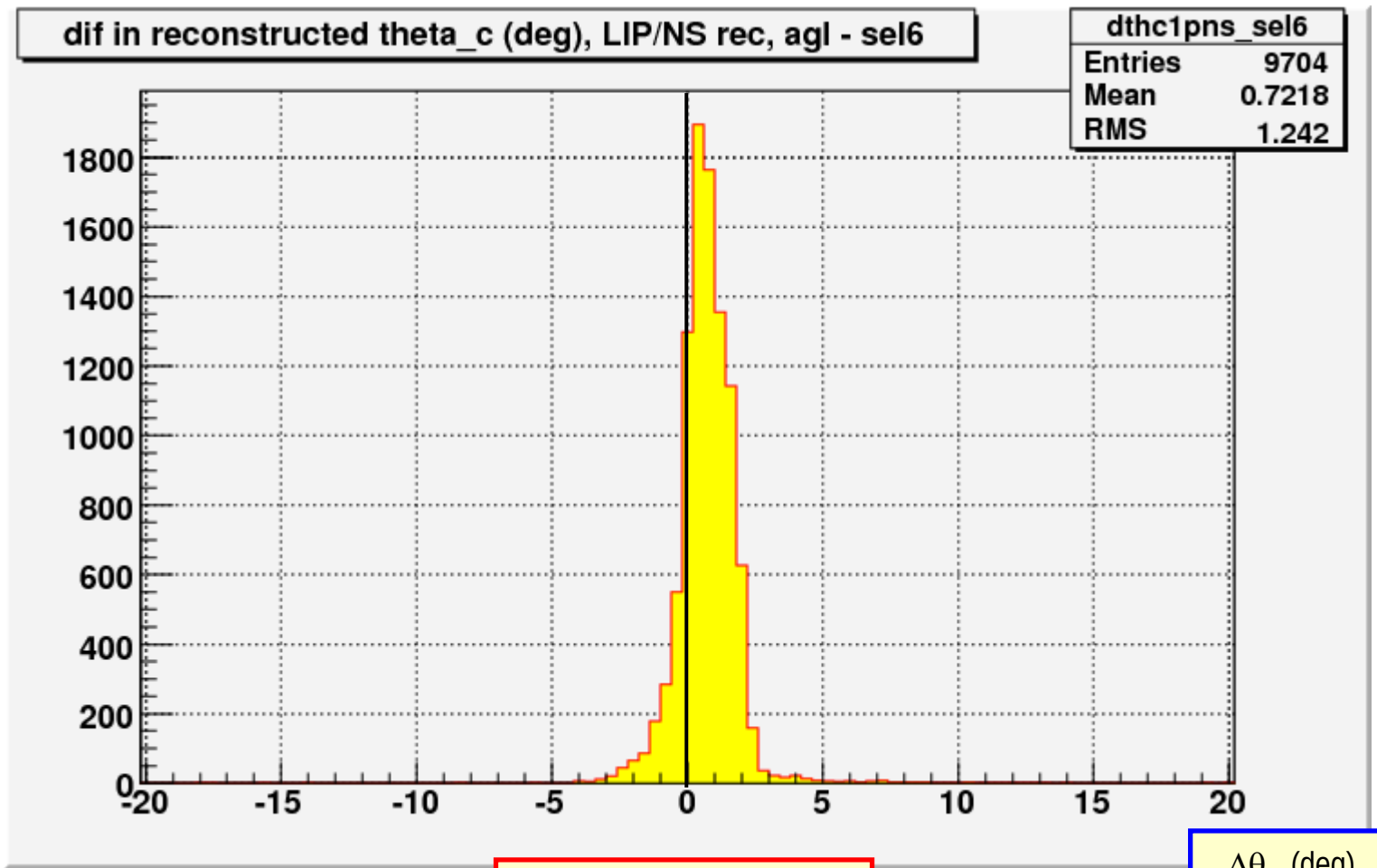


after cuts

after cuts, 6+ hits

bars show RMS of distributions

Reconstruction quality: θ_c

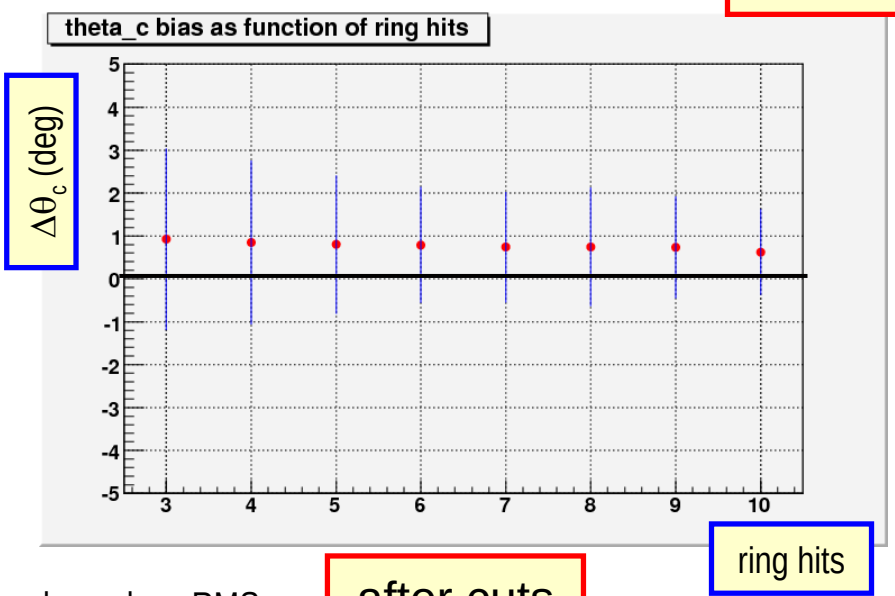


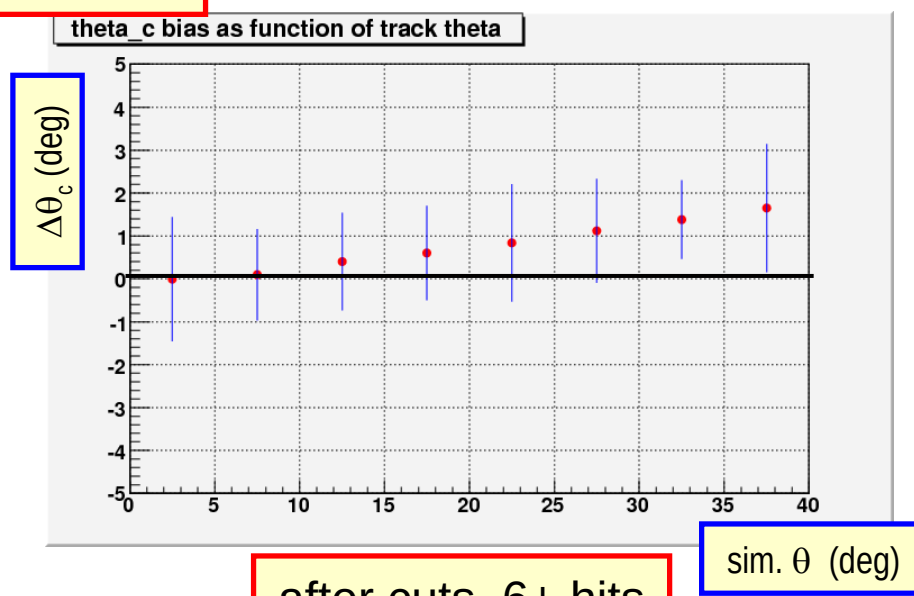
after cuts, 6+ hits

Reconstruction quality: θ_c, all events

- Significant bias in θ_c reconstruction
  - Average bias slightly under 1°, almost independent of number of ring hits
  - No bias for vertical events, reaches 1.5° for higher θ

ALL EVENTS





after cuts

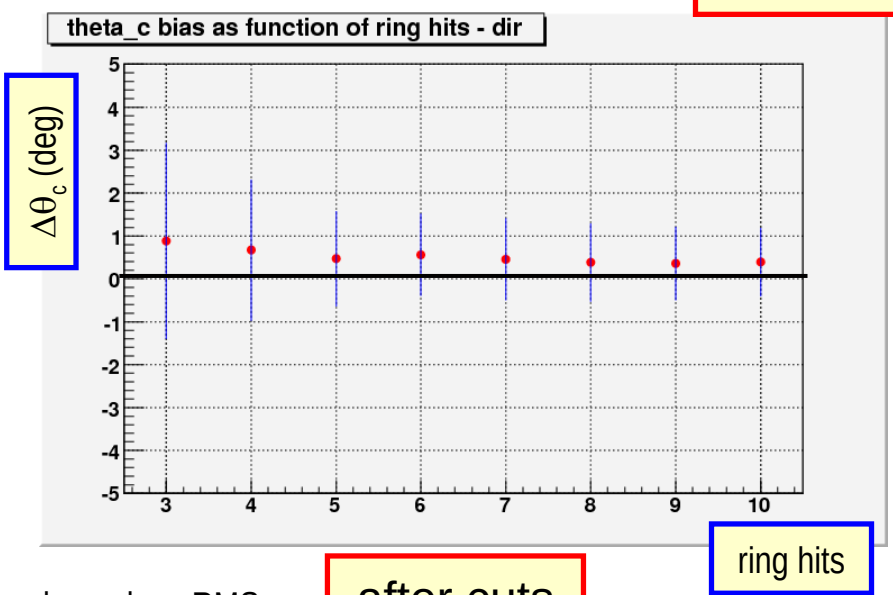
after cuts, 6+ hits

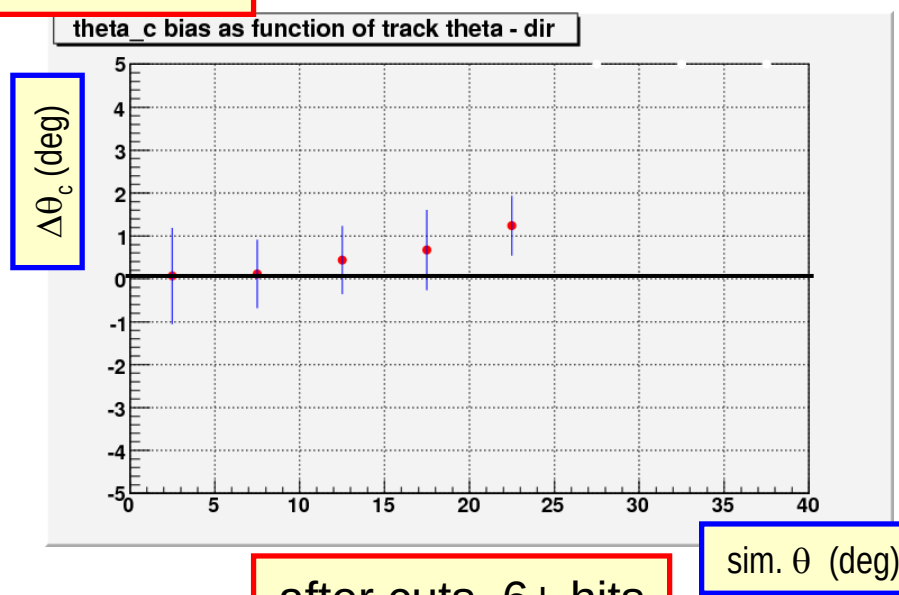
bars show RMS of distributions

Reconstruction quality: θ_c, direct events

- Direct events (r_{hint} < 42 cm):
  - Lower average bias, essentially due to lower θ
  - Average bias ~0.5° for high number of hits

DIRECT EVENTS





after cuts

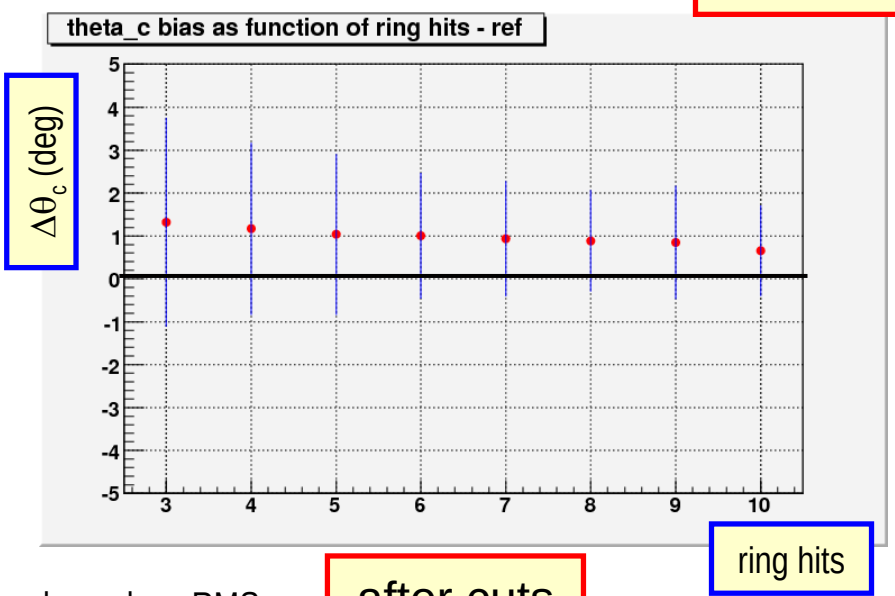
after cuts, 6+ hits

bars show RMS of distributions

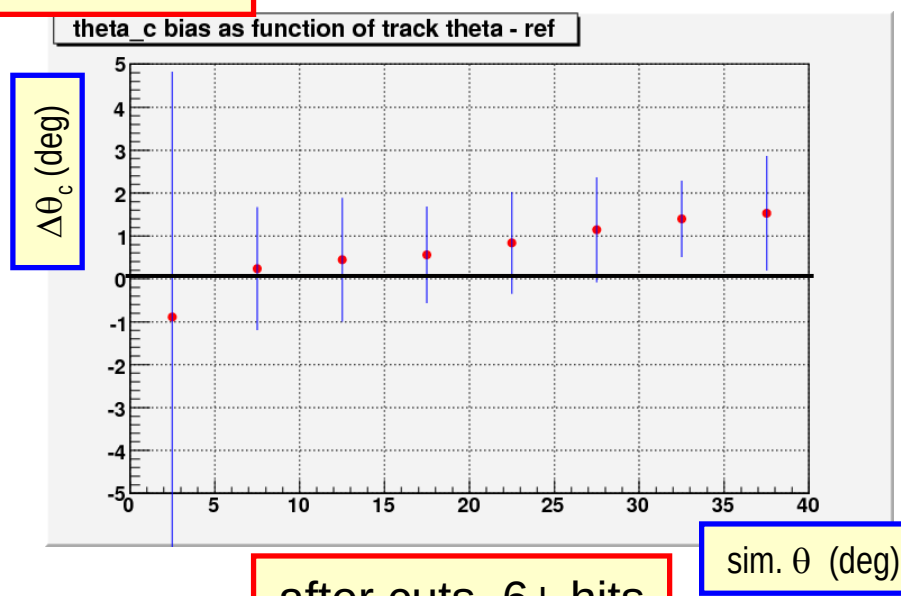
Reconstruction quality: θ_c, mirror events

- Mirror events (r_{hint} > 55 cm):
  - Larger bias due to larger average θ
  - Evolution with θ similar to what is seen using all events

MIRROR EVENTS



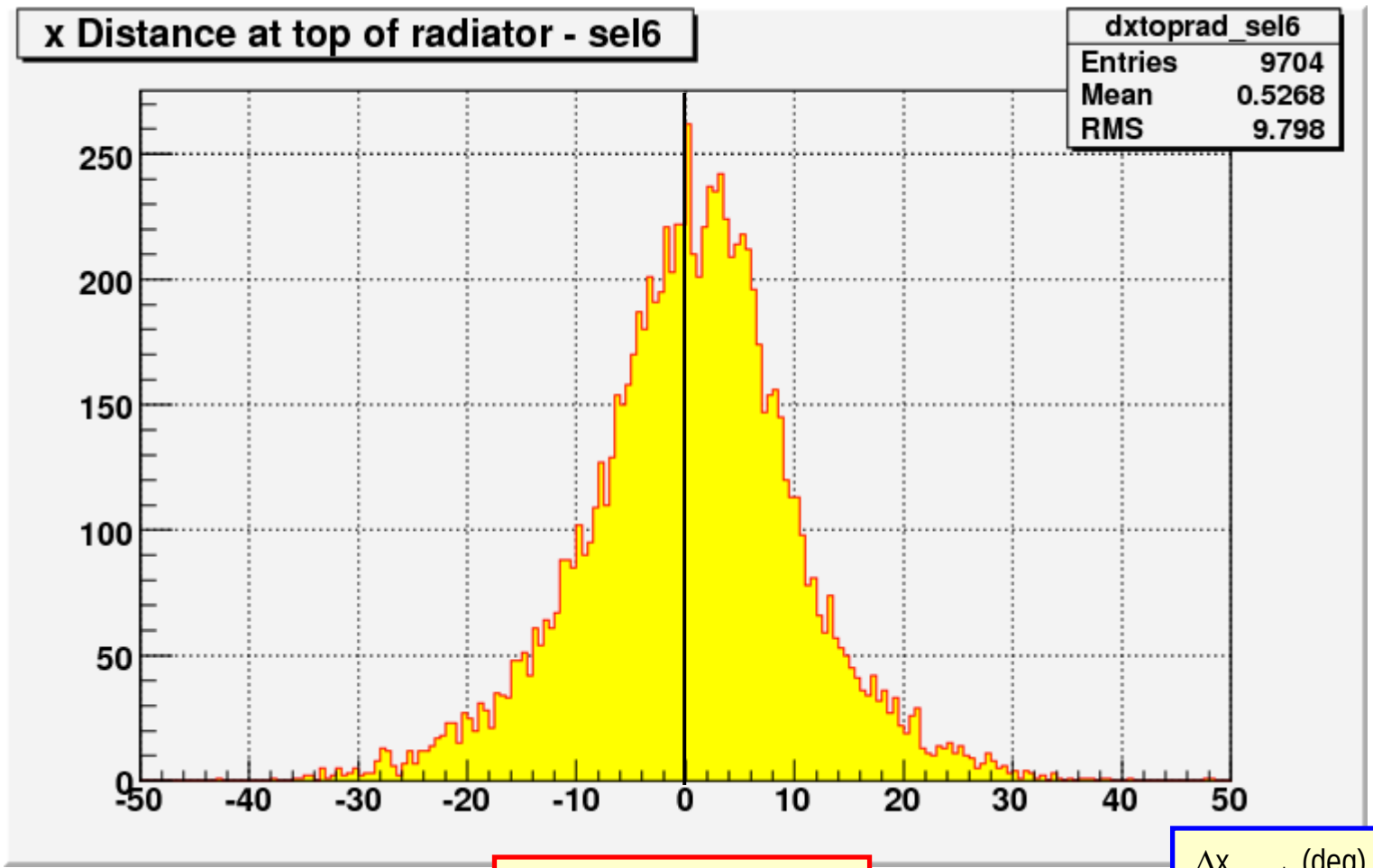
after cuts



after cuts, 6+ hits

bars show RMS of distributions

Reconstruction quality: $x_{top\text{-}rad}$

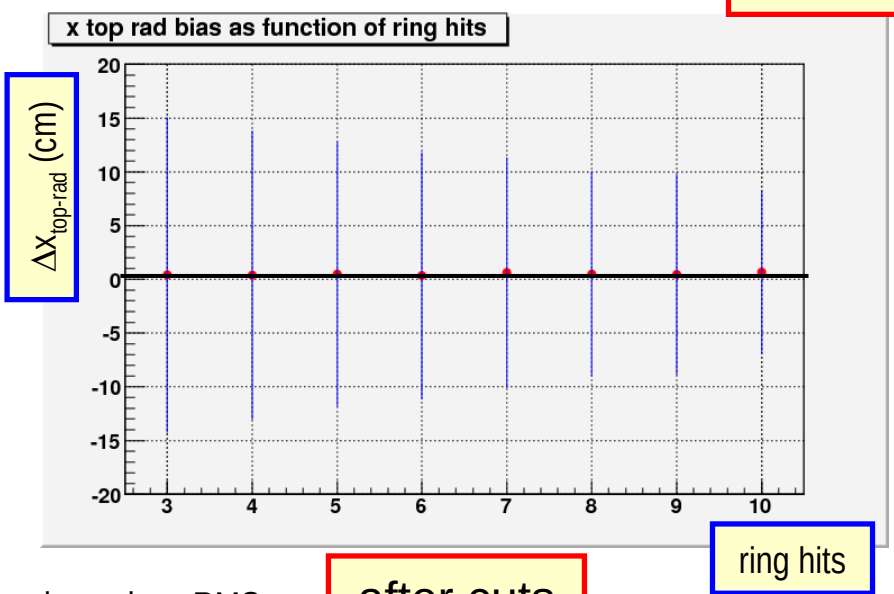


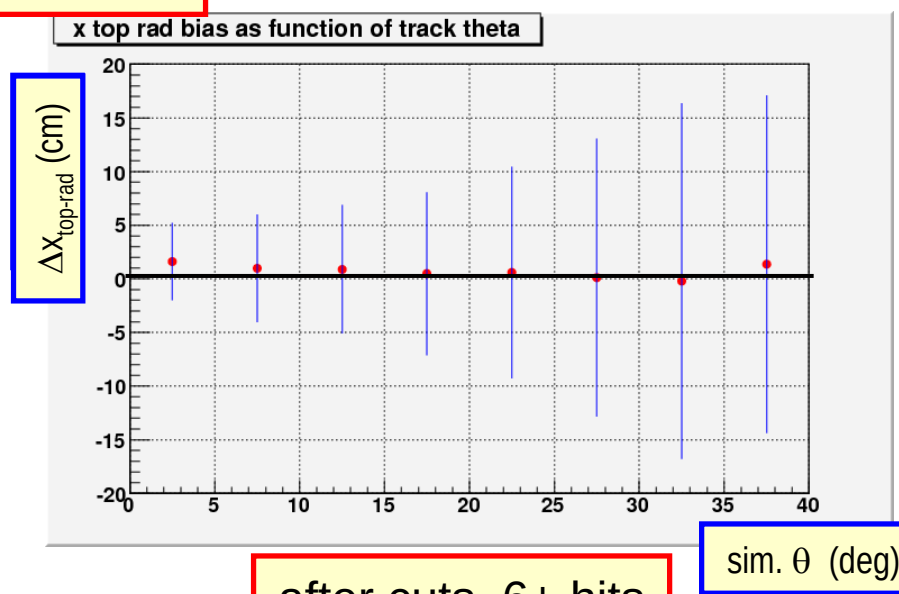
after cuts, 6+ hits

Reconstruction quality: $x_{top\text{-}rad}$, all evts

- x coordinate at top of radiator:
  - Spread becomes smaller as number of ring hits increases
  - Strong increase in spread with theta
  - Slight bias (< 1 cm) possibly due to reconstruction method
  - Similar results for $y_{top\text{-}rad}$

ALL EVENTS





after cuts

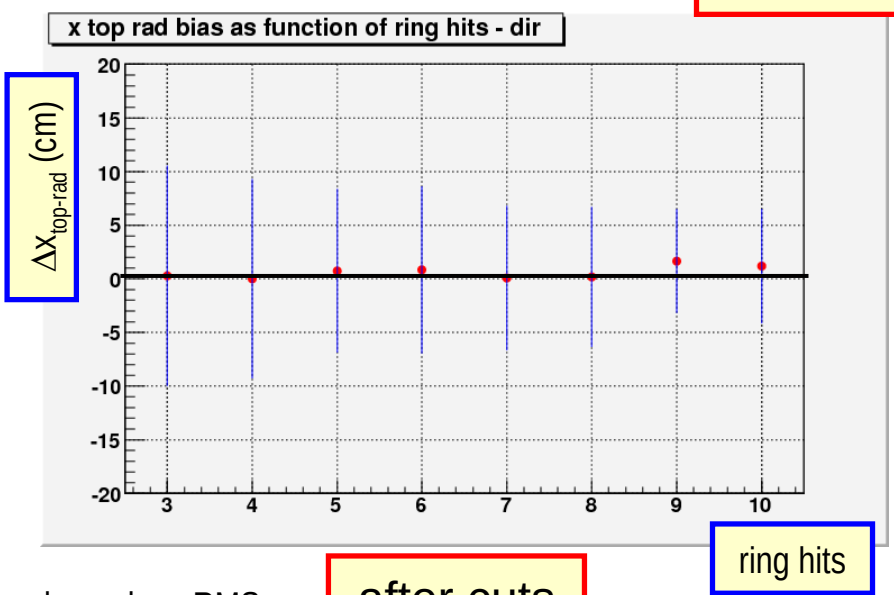
after cuts, 6+ hits

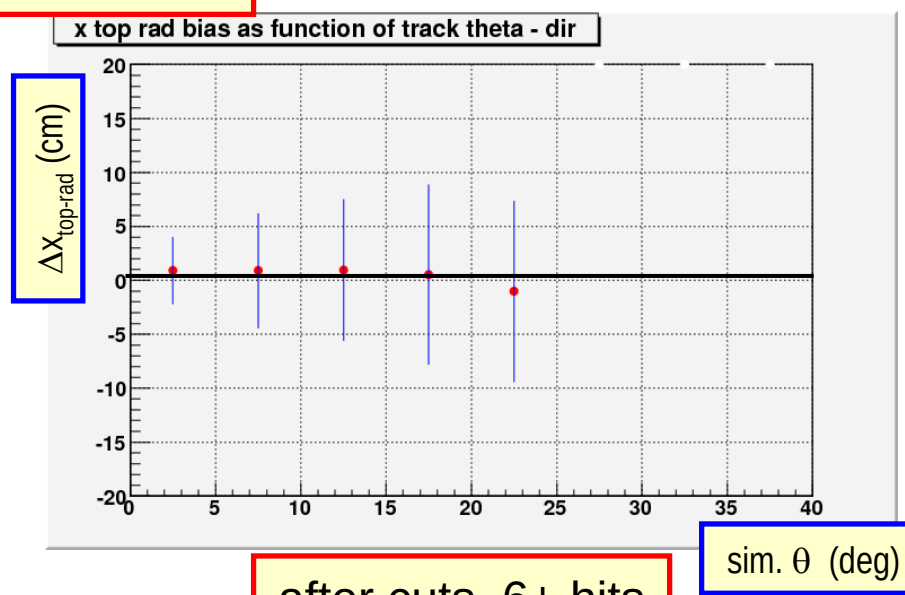
bars show RMS of distributions

Reconstruction quality: $x_{top\text{-}rad}$, dir evts

- Direct events (r_{hint} < 42 cm):
  - Smaller spread for same number of hits due to lower θ
  - Similar spread of global sample at comparable θ regions

DIRECT EVENTS





after cuts

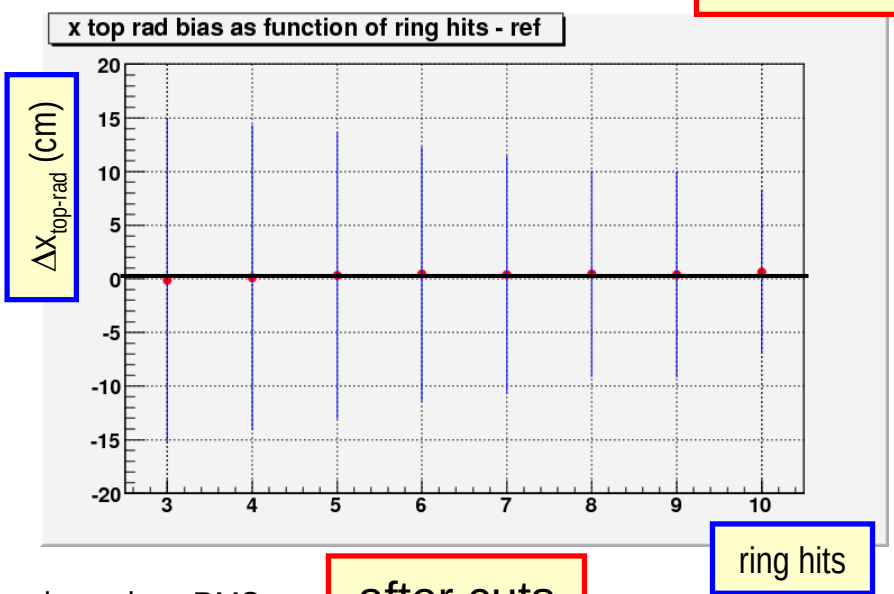
after cuts, 6+ hits

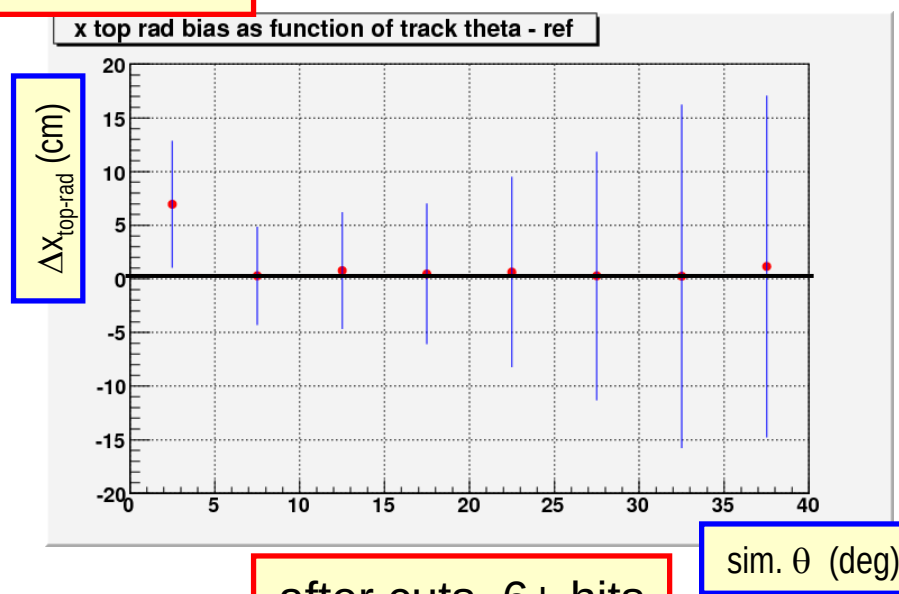
bars show RMS of distributions

Reconstruction quality: $x_{top\text{-}rad}$, mir evts

- Mirror events (r_{hint} > 55 cm):
  - Larger spread due to larger average θ
  - Evolution with θ similar to what is seen using all events
  - Spread slightly smaller than what is seen for direct events (mirror events have higher number of hits)

MIRROR EVENTS



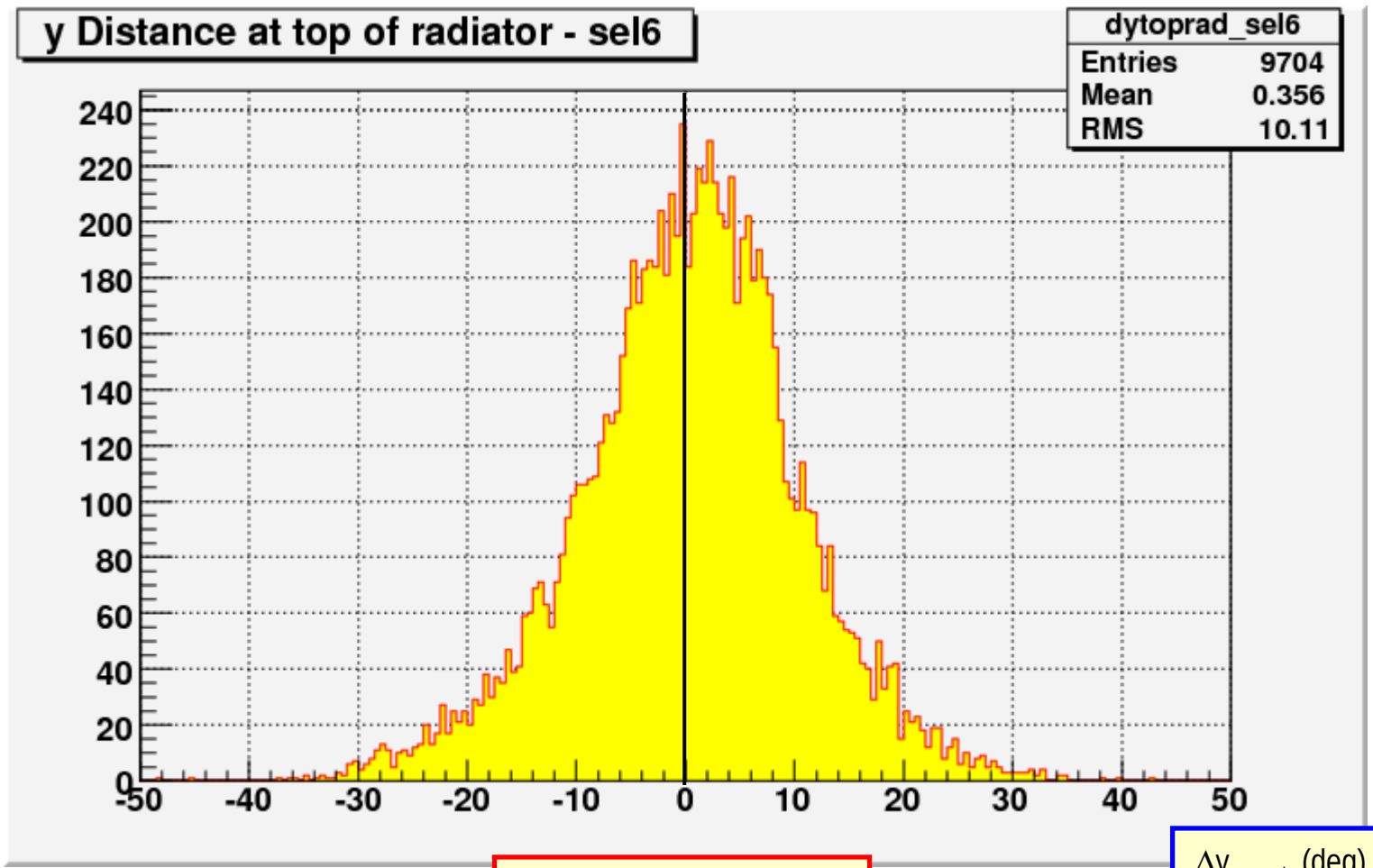


after cuts

after cuts, 6+ hits

bars show RMS of distributions

Reconstruction quality: $y_{top\text{-}rad}$



after cuts, 6+ hits

Conclusions & future work

- Standalone reconstruction in the AMS RICH has been studied
- Main problem is θ reconstruction – strong bias towards lower values
  - Bias is smaller for central events
  - Events with high number of hits have smaller bias
- Bias in θ_c (related to bias in θ)
  - Reconstructed θ_c is typically ~1° higher than simulated value
  - resolution in θ_c ~1° (4 $\times$ typical resolution for 1-parameter rec)
- Different (θ,θ_c) pairs can produce almost degenerate rings
- Correlation between simulated and reconstructed ϕ
  - Uncertainty is ~30°-60° for typical proton events

- Future work will include:
  - Improvements on standalone reconstruction procedure to reduce bias in θ
  - Study of higher charges to gauge the evolution of bias with number of hits