Status of stand-alone muon reconstruction in CMSSW

Daniele Trocino
INFN and University of Torino

Torino CMS group weekly meeting
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Outline

- Introduction
  - quick description of Kalman Filter procedure
  - stand-alone muon reconstruction in CMSSW
- Current status of stand-alone reconstruction
  - problems at high $|\eta|$
  - quality cuts on track/segments
  - effects on global reconstruction
- Possible improvements and ongoing work

The Kalman Filter (I)

- In CMS it is used to reconstruct the trajectory of a charged particle
  - in a magnetic field, the trajectory is a helix → **5 parameters**:

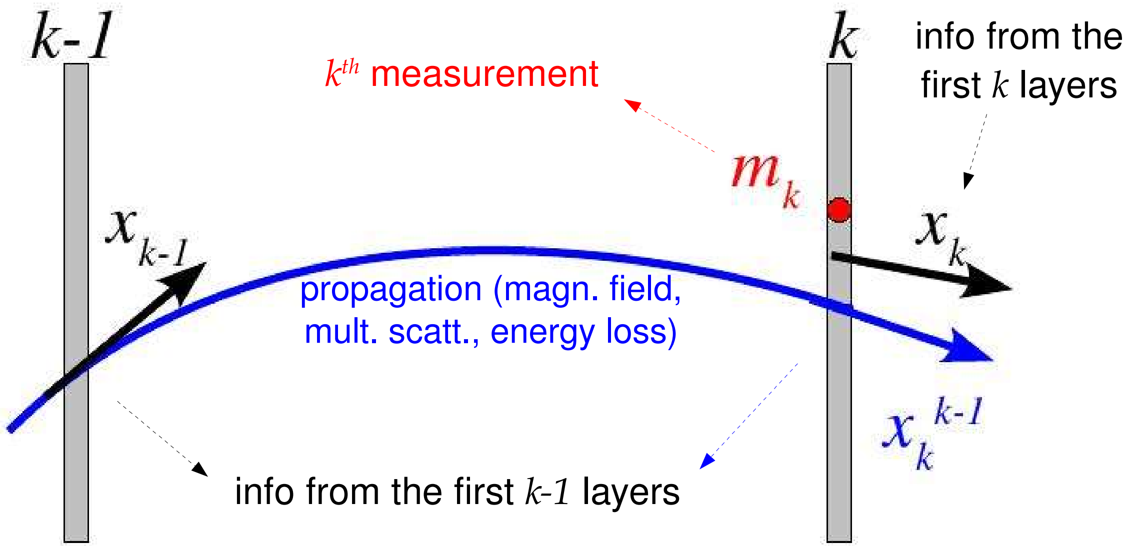
    x = (charge/momentum, position and direction on a given surface)

- Kalman Filter allows at the same time to
  - perform the *pattern recognition* (→ collection of hits)
  - have the best estimation of the track (→ minimum χ^2)

- Requirements:
  - it must take into account *energy loss* and *multiple scattering*
  - it must be **fast** (→ well suited for HLT)

- It is used both in the Muon System and in the Tracker (*stand-alone*, *tracker* and *global* muon reconstruction)

The Kalman Filter (II)

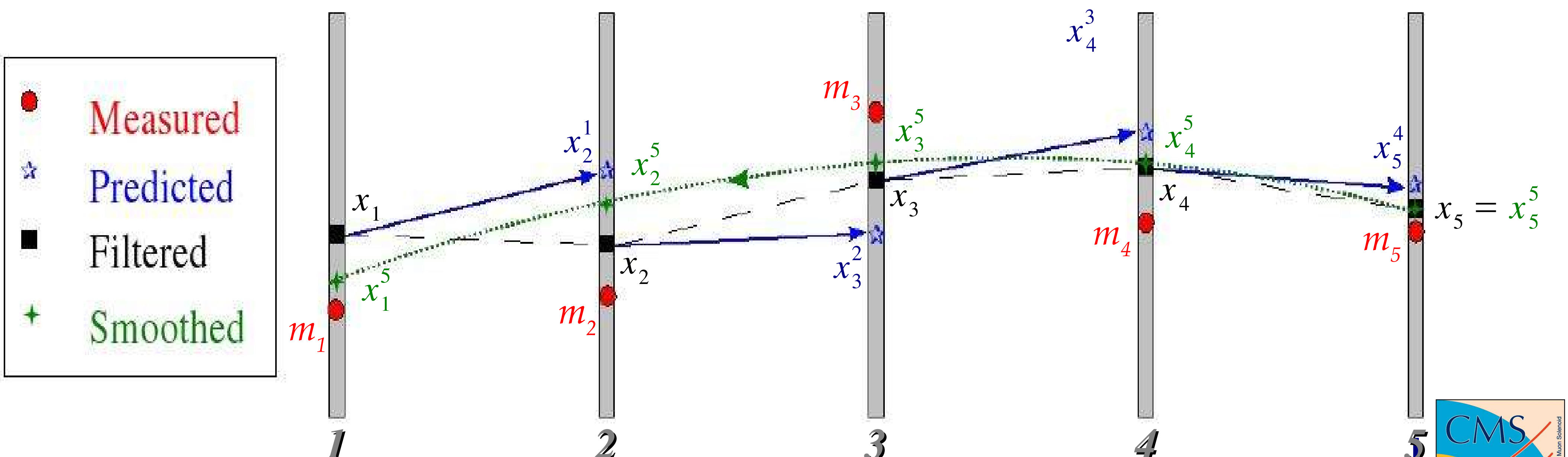


m_k = measurement on the k^{th} layer

x_k^{k-1} = state on the k^{th} layer, with info from the first k-1 layers (***predicted***)

x_k = state on the k^{th} layer, with info from the first k layers (***filtered***)

x_k^N = state on the k^{th} layer, with info from all the N layers (***smoothed***)



Stand-alone track reconstruction in CMSSW

Starts from an initial state (*seed*):

- built from one or more segments
- p_T parametrized as a function of ϕ (or $\Delta\phi$) of segments
- different seeding algorithms exist

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1- pattern recognition (KF based, *no smoothing*):

- on each layer, search for the *most compatible* segment (hit in RPC) based on χ^2
- trajectory parameters updated with the chosen RecHit(s) (segment or its hits)
- 2 filtering steps performed (by default)
  - forward (inside-out): update with segment granularity
  - backward (outside-in): update with hit granularity

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1- pattern recognition (KF based, *no smoothing*):

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- 2 filtering steps performed (by default)
  - forward (inside-out): update with segment granularity
  - backward (outside-in): update with hit granularity

2- refit (KF, *filter + smoother*, no pattern recognition):

- initial state from fw/bw filter, error enlarged to avoid biases
- use of RecHits (hits or segments) *previously collected*
- refit performed *n* times (3 by default), limit on max # lost hits (5% by default)

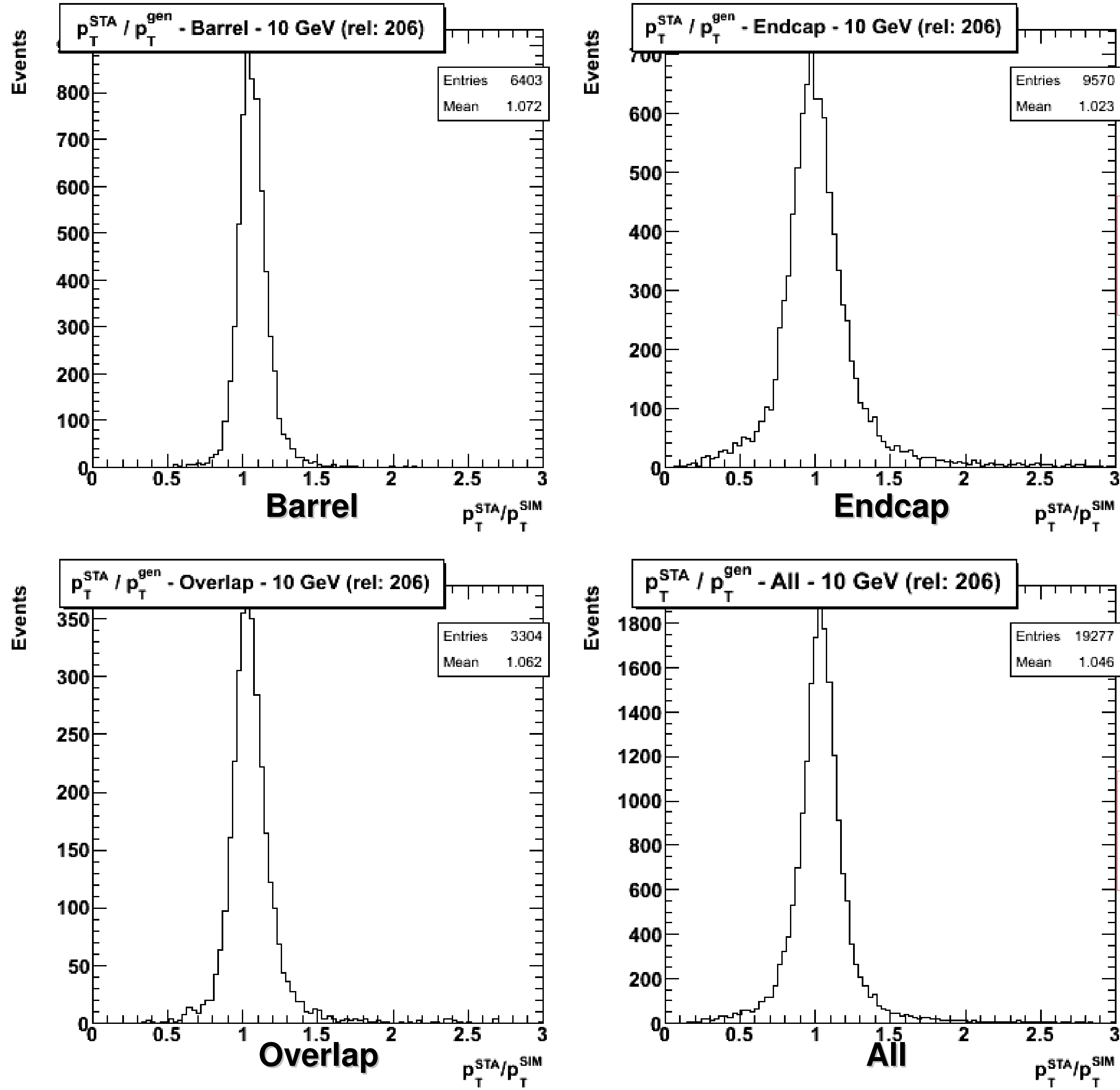
Not yet in standard offline reco

Recently **included** in L2 muon trigger reco

p_T^{sta}/p_T^{gen} – CMSSW_2_0_6 (10 GeV)

Wrong charge: 0.31%

Wrong charge: 3.62%

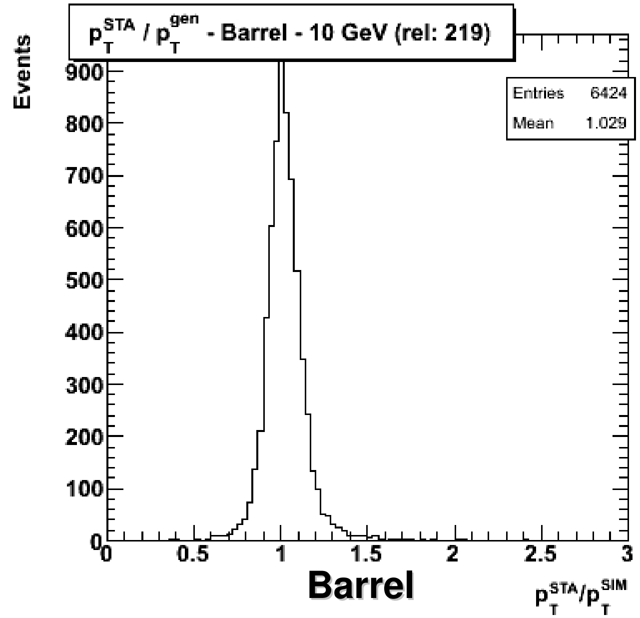


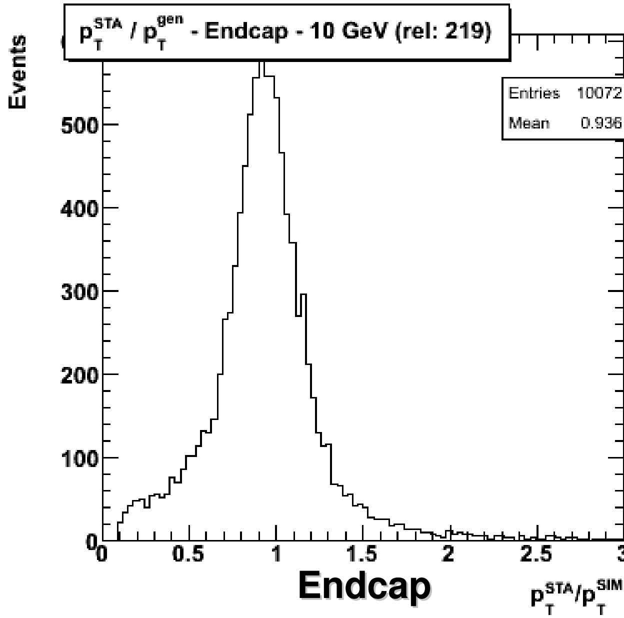
Wrong charge: 0.91%

Wrong charge: 2.05%

p_T^{sta}/p_T^{gen} – CMSSW_2_1_9 (10 GeV)

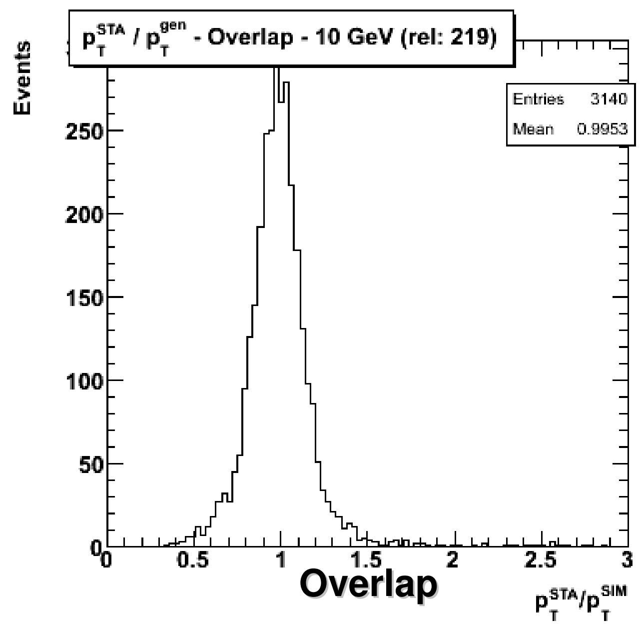
Wrong charge:
0.54%

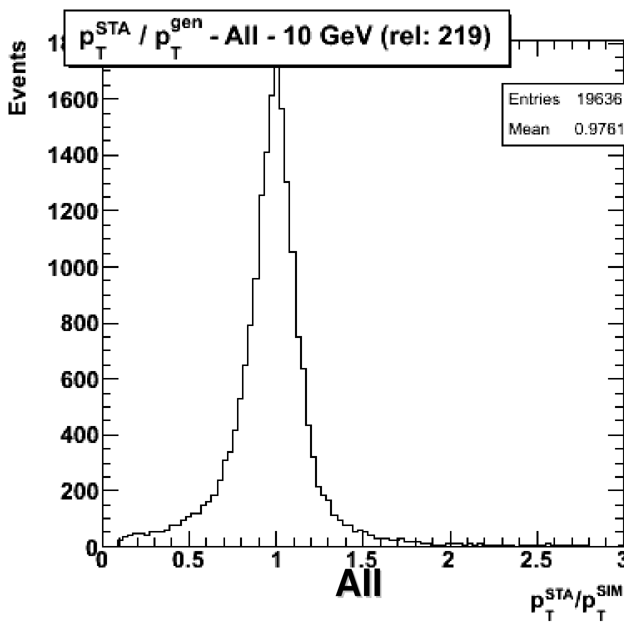




Wrong charge:
6.18%

Wrong charge:
1.53%

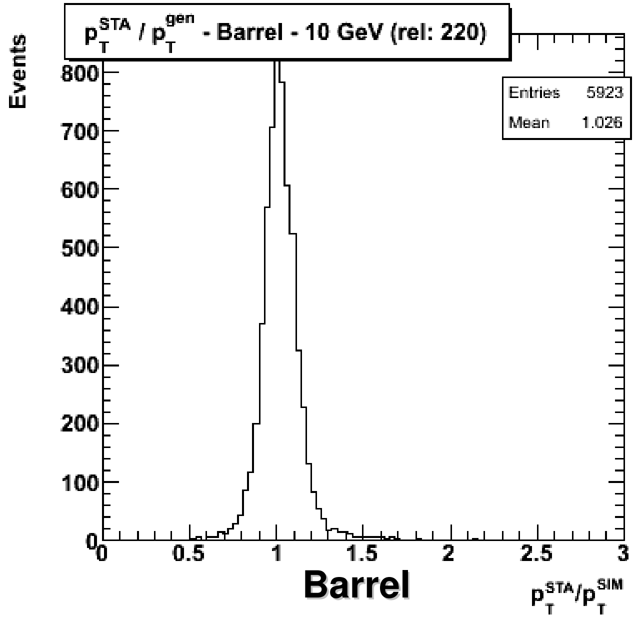




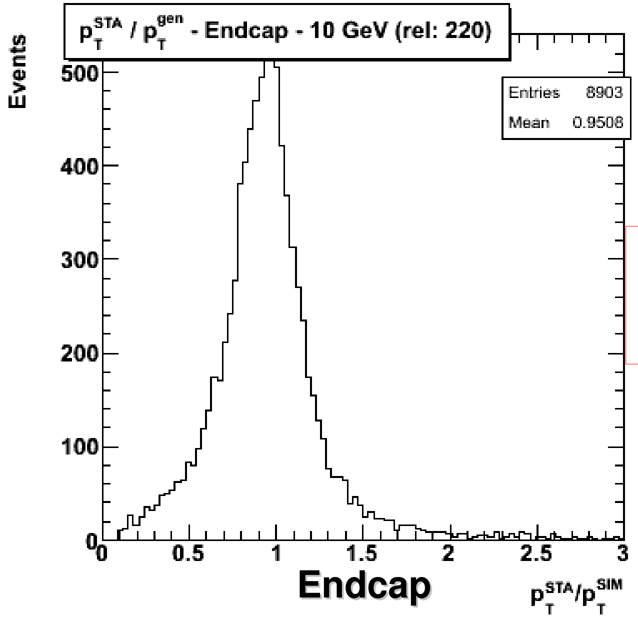
Wrong charge:
3.59%

p_T^{sta}/p_T^{gen} – CMSSW_2_2_0 (10 GeV)

Wrong charge: 0.37%



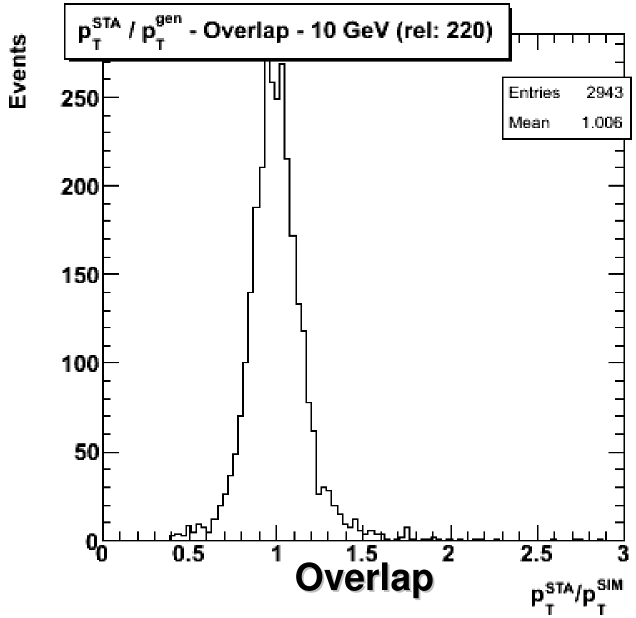
Barrel



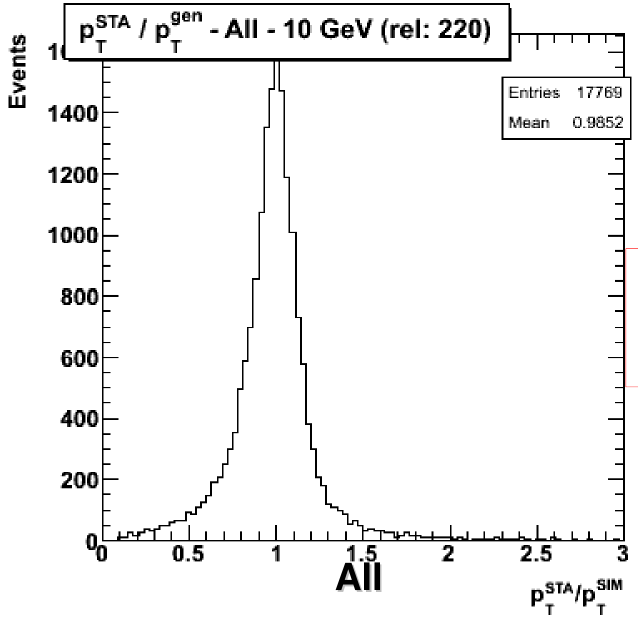
Endcap

Wrong charge: 6.05%

Wrong charge: 1.26%



Overlap



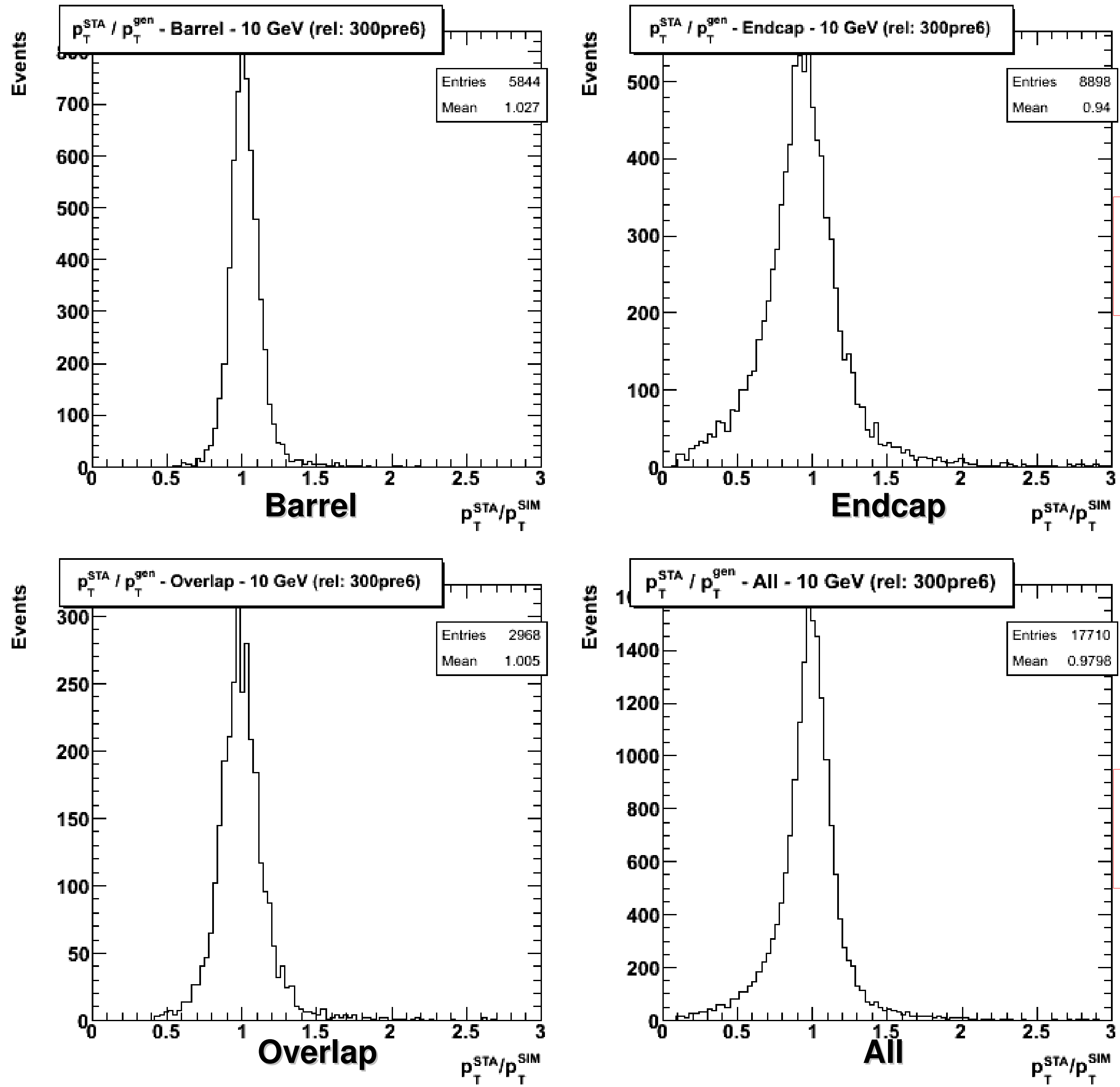
All

Wrong charge: 3.37%

p_T^{sta}/p_T^{gen} – CMSSW_3_0_0_pre6 (10 GeV)

Wrong charge: 0.41%

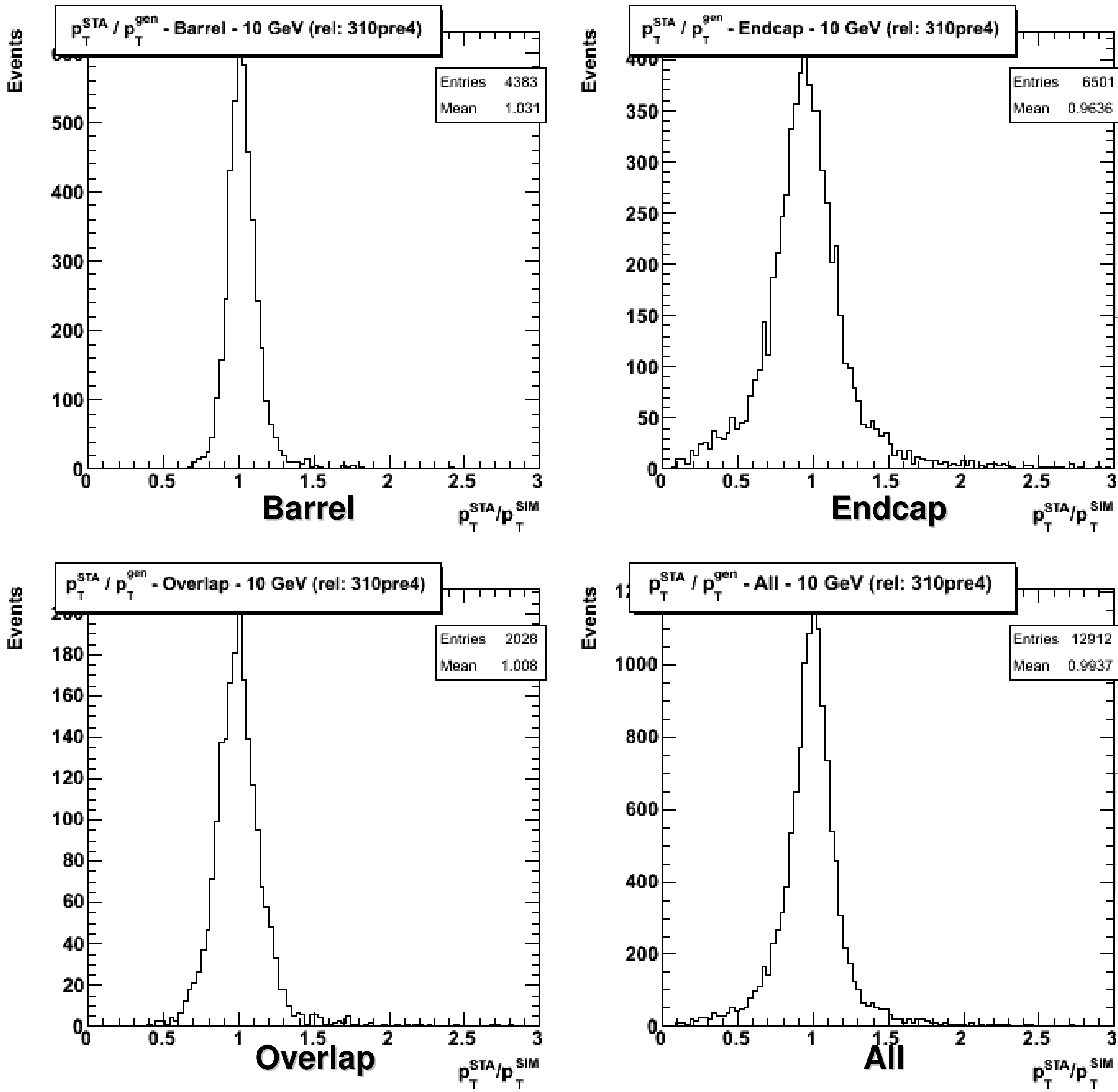
Wrong charge: 5.23%



Wrong charge: 1.18%

Wrong charge: 2.96%

p_T^{sta}/p_T^{gen} – CMSSW_3_1_0_pre4 (10 GeV)



Wrong charge: 0.23% (Barrel)

Wrong charge: 5.55% (Endcap)

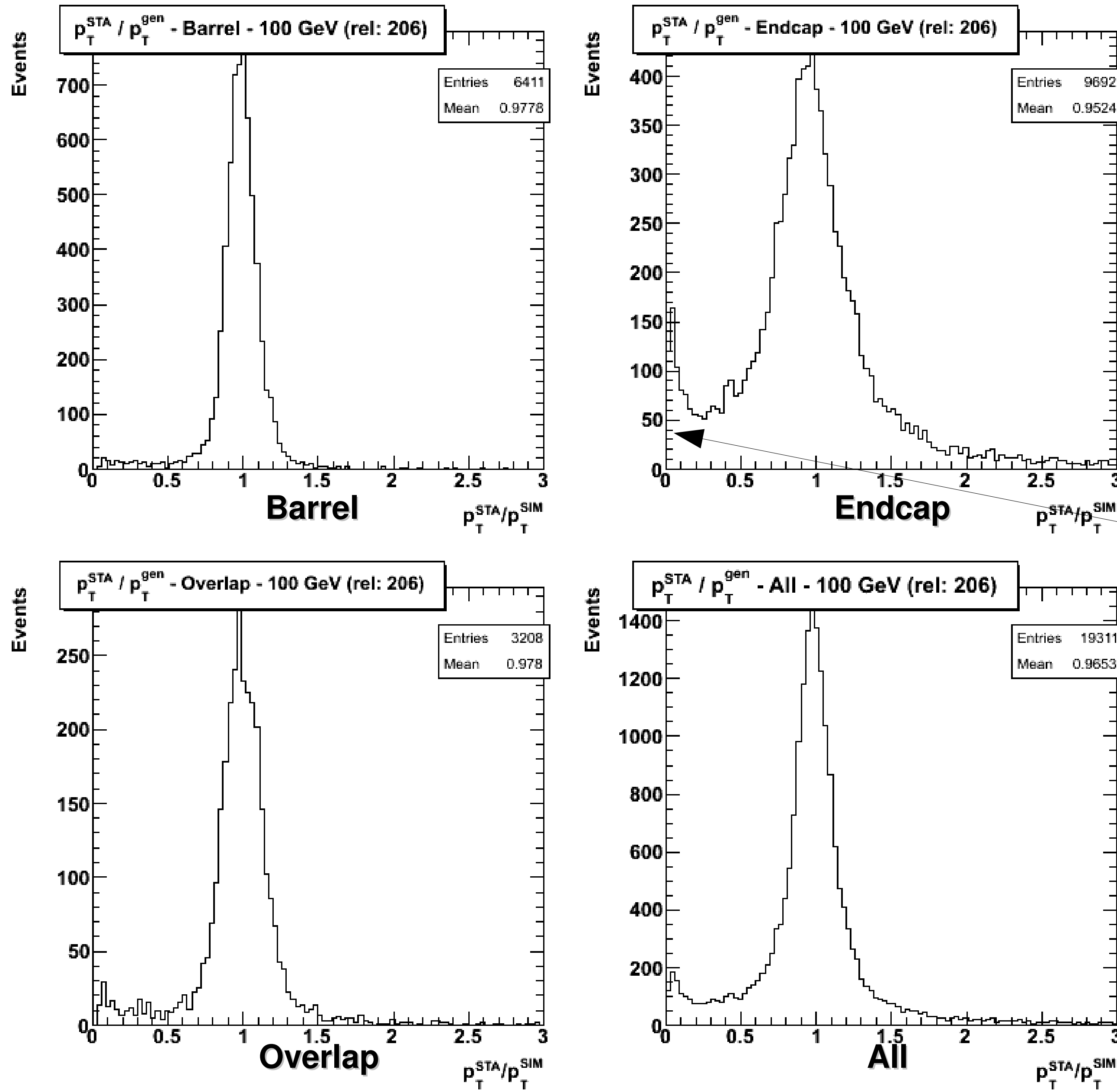
Wrong charge: 1.53% (Overlap)

Wrong charge: 3.14% (All)

p_T^{sta}/p_T^{gen} – CMSSW_2_0_6 (100 GeV)

Wrong charge: 1.34%

Wrong charge: 12.53%



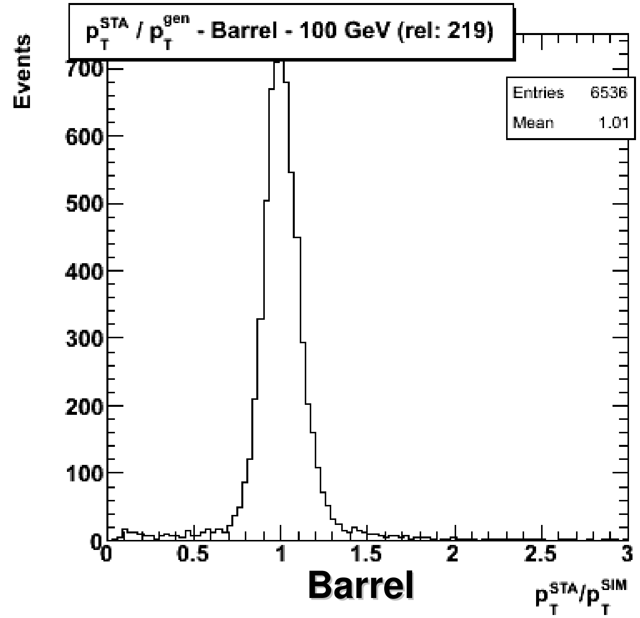
peak does not show up in FastSim!
(no δ-rays, no showering)

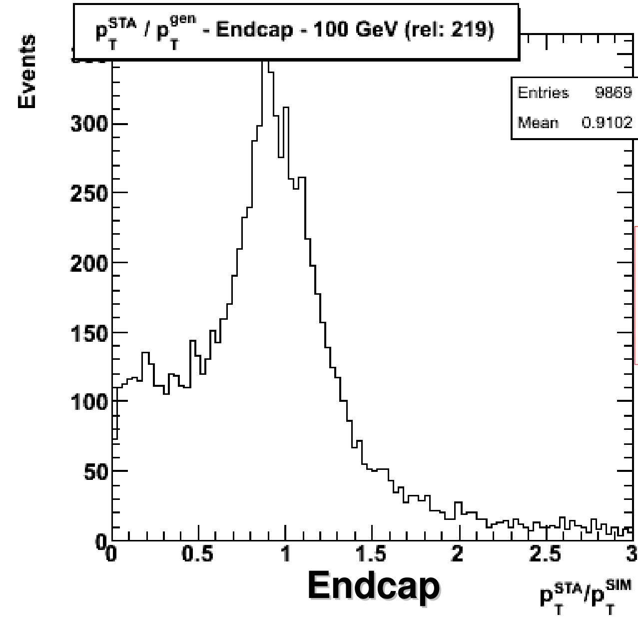
Wrong charge: 5.42%

Wrong charge: 7.63%

p_T^{sta}/p_T^{gen} – CMSSW_2_1_9 (100 GeV)

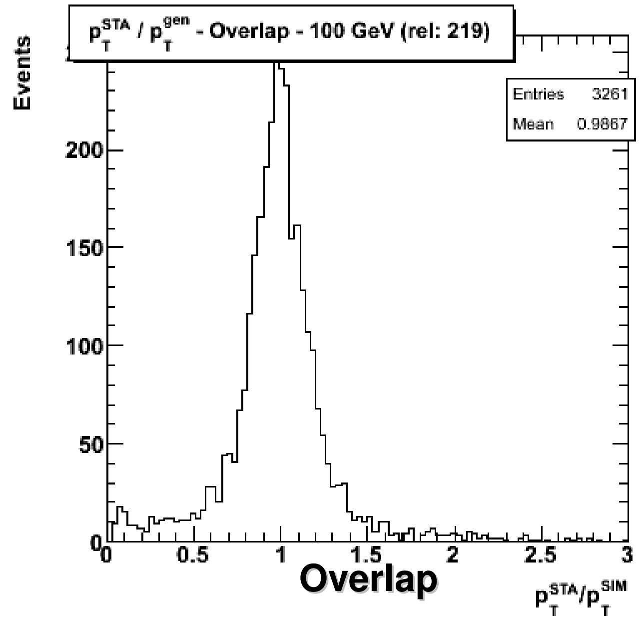
Wrong charge: 2.08%

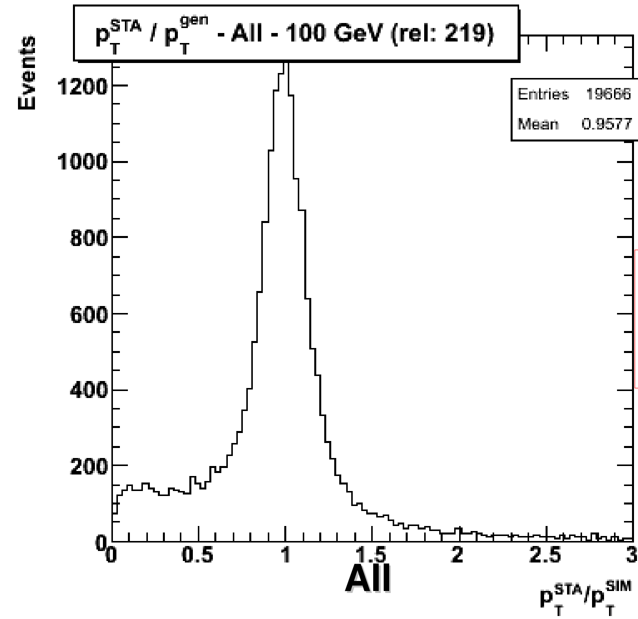




Wrong charge: 18.07%

Wrong charge: 6.04%



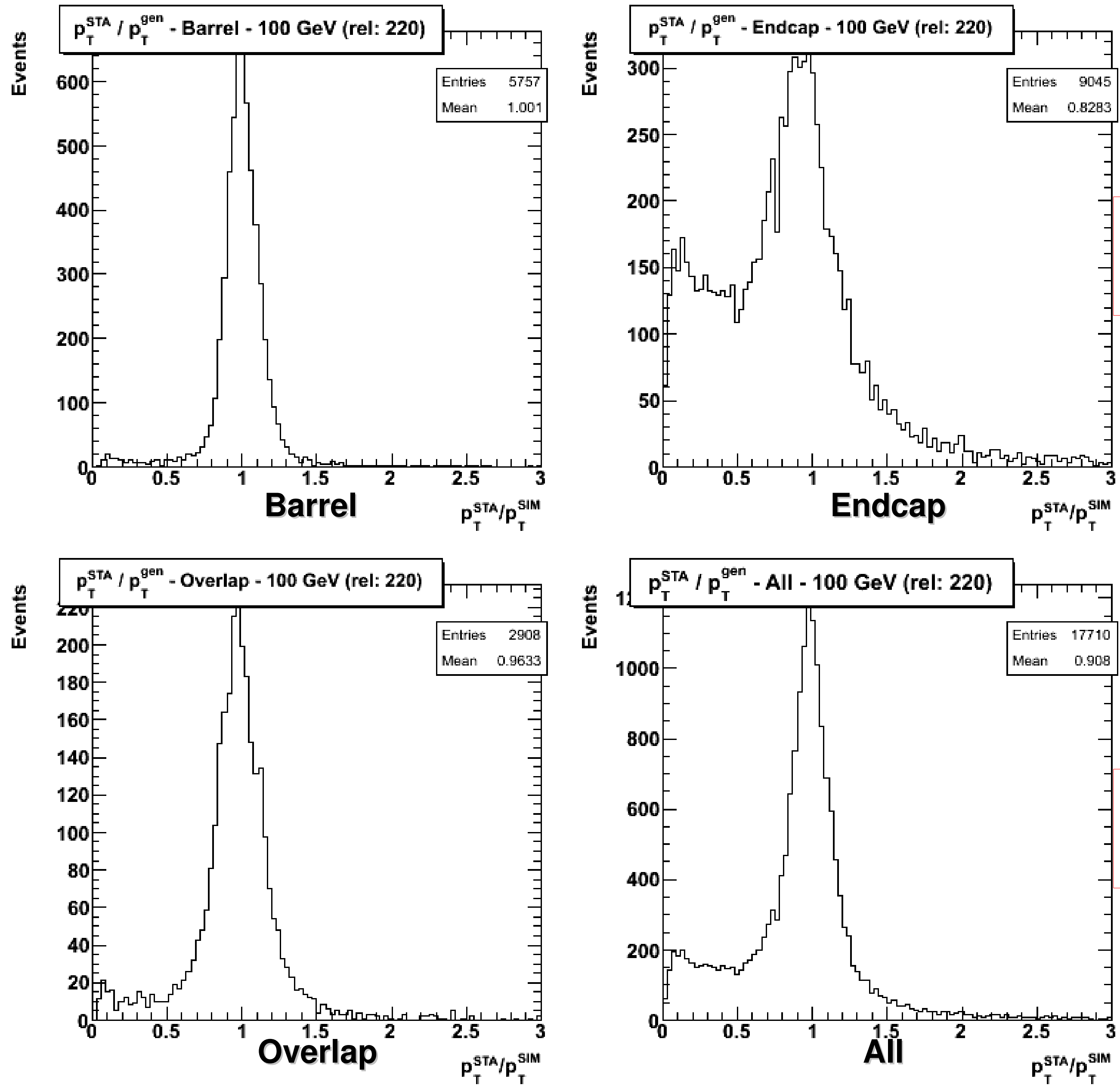


Wrong charge: 10.76%

p_T^{sta}/p_T^{gen} – CMSSW_2_2_0 (100 GeV)

Wrong charge: 1.82%

Wrong charge: 20.31%

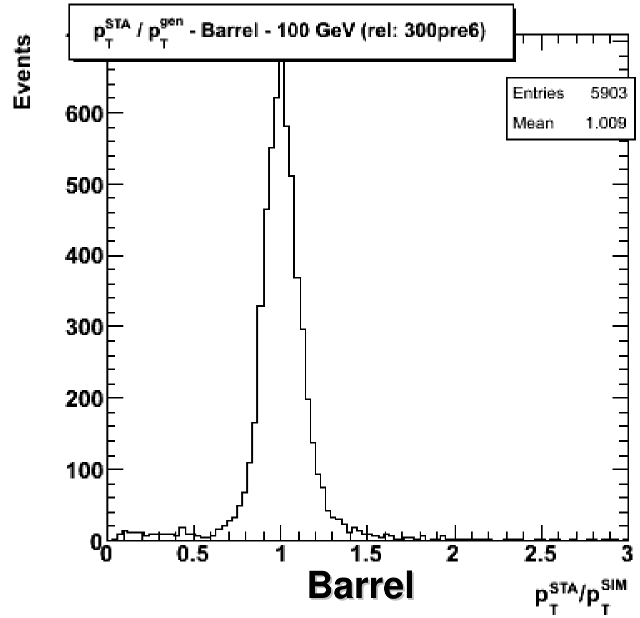


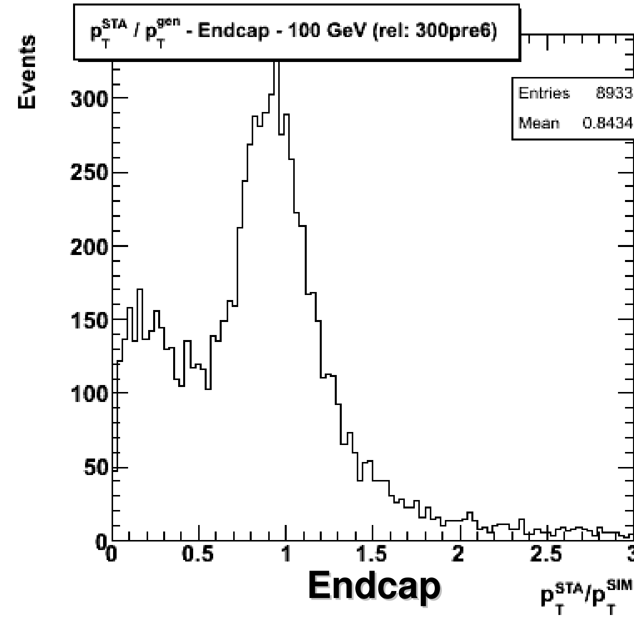
Wrong charge: 6.40%

Wrong charge: 12.02%

p_T^{sta}/p_T^{gen} – CMSSW_3_0_0_pre6 (100 GeV)

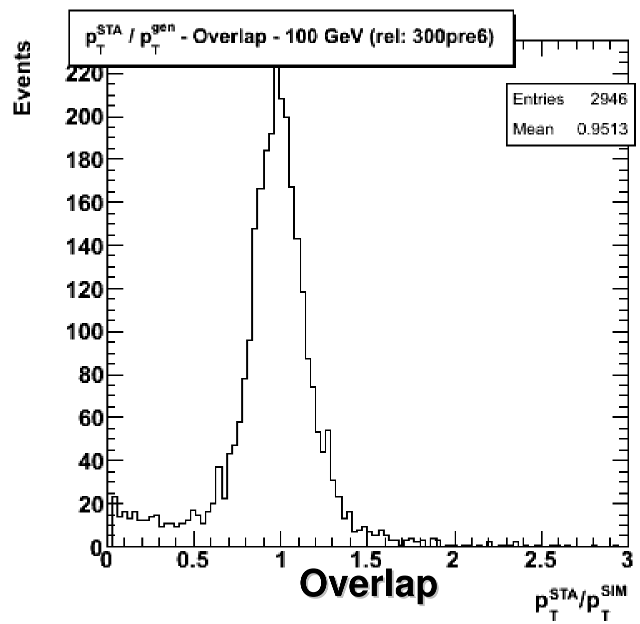
Wrong charge: 2.22%

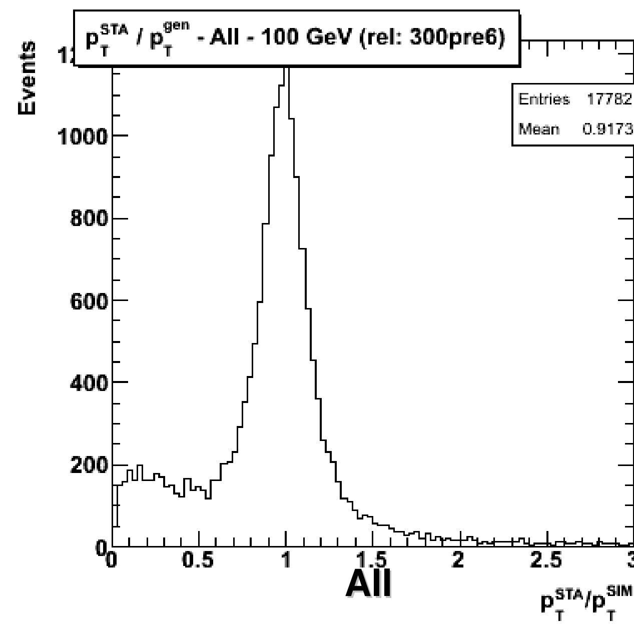




Wrong charge: 19.68%

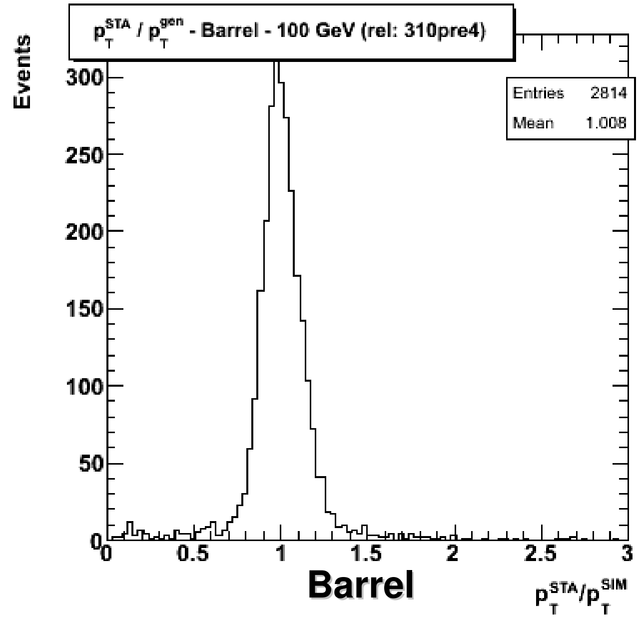
Wrong charge: 6.79%



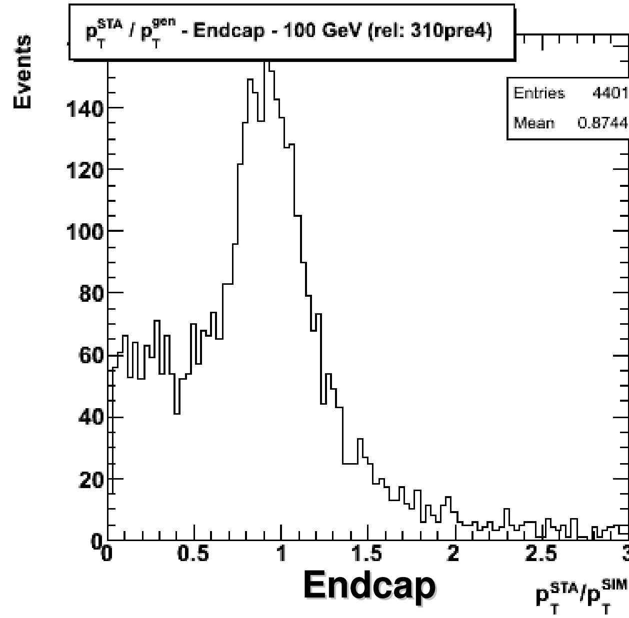


Wrong charge: 11.75%

p_T^{sta}/p_T^{gen} – CMSSW_3_1_0_pre4 (100 GeV)



Wrong charge: 2.06%



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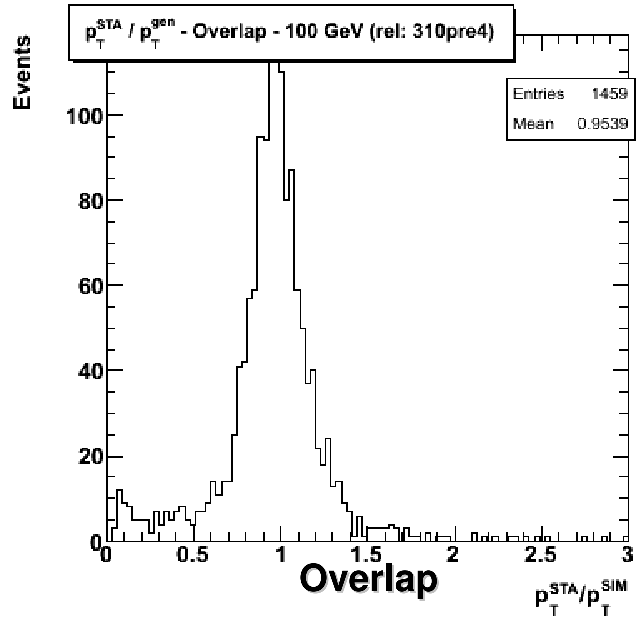
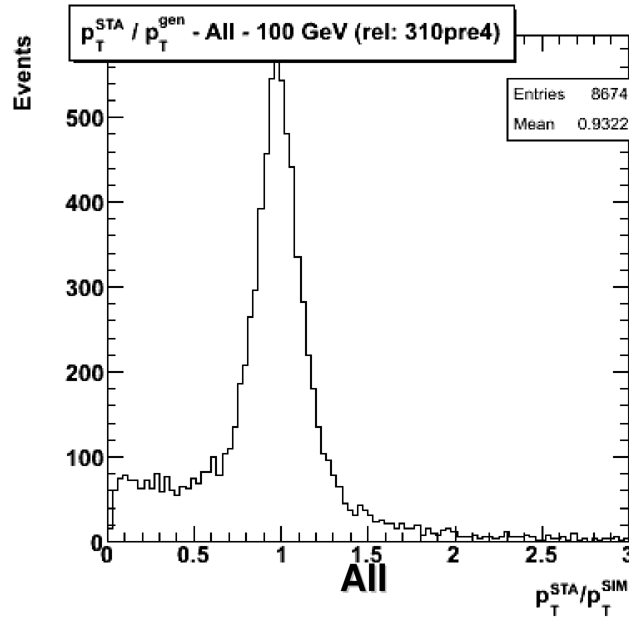


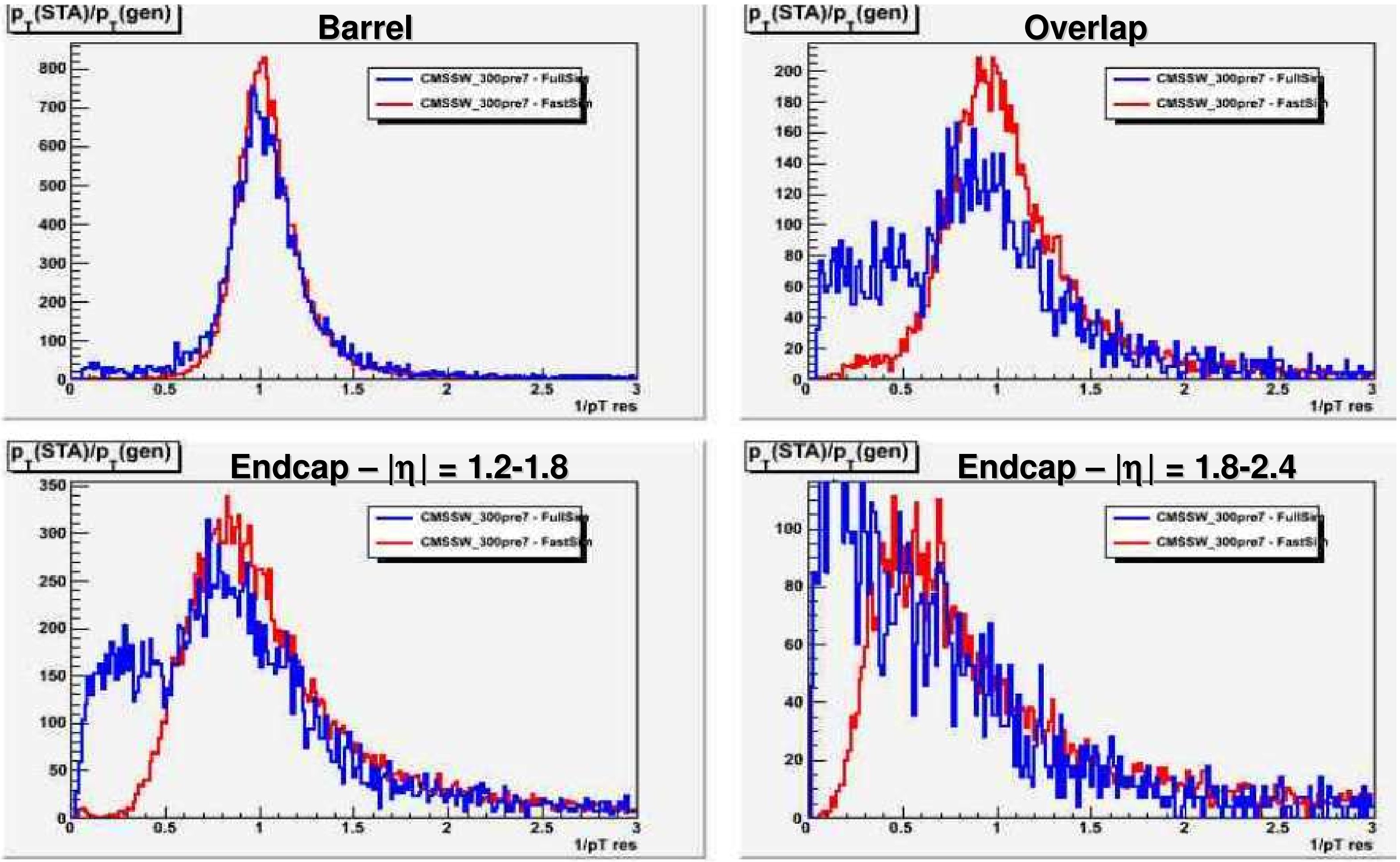
Wrong charge: 6.79%



Wrong charge: 11.28%

FullSim vs FastSim

100 GeV - 300pre7

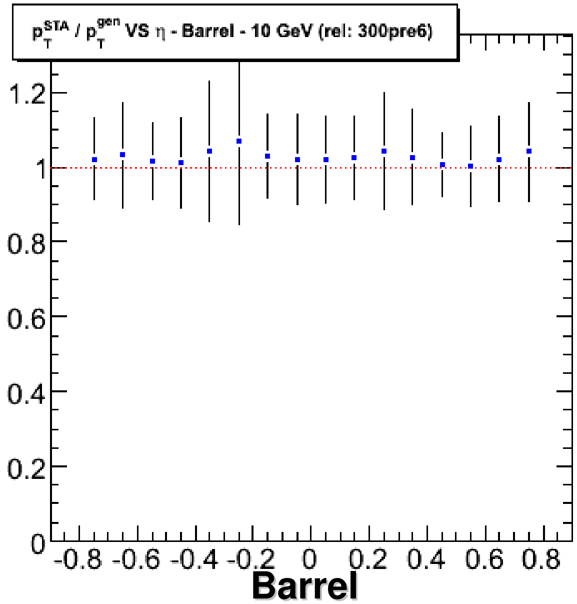


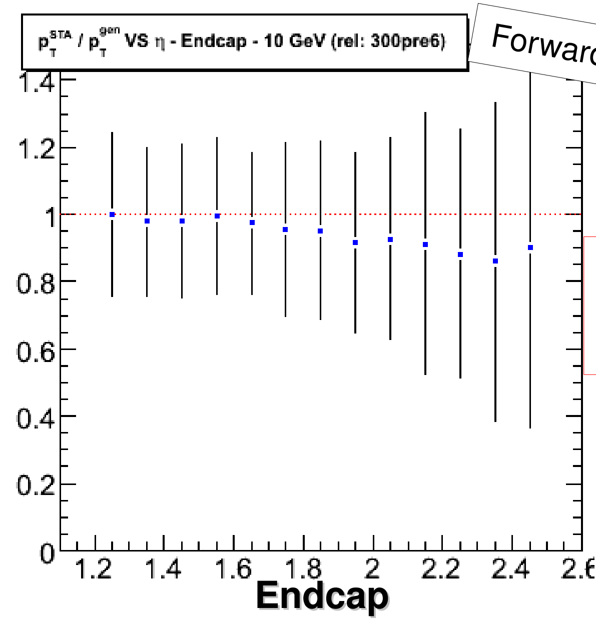
— FastSim
— FullSim

A. Perrotta
https://cmsdoc.cern.ch/cms/Physics/muon/CMSSW/Performance/Fastsim/plots/FASTvsFULL/FastMuonValidation-300pre7.pdf

p_T^{sta}/p_T^{gen} vs η – 300pre6 (10 GeV)

Wrong charge: 0.41%



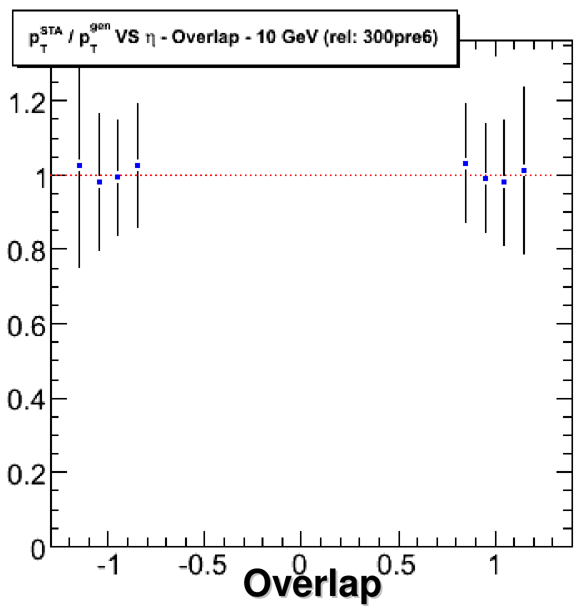


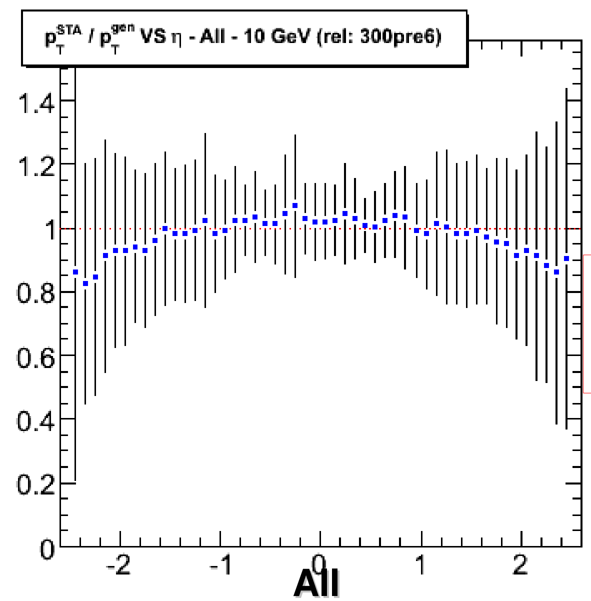
Forward only

Wrong charge: 5.23%

Mean value and RMS (no fit)

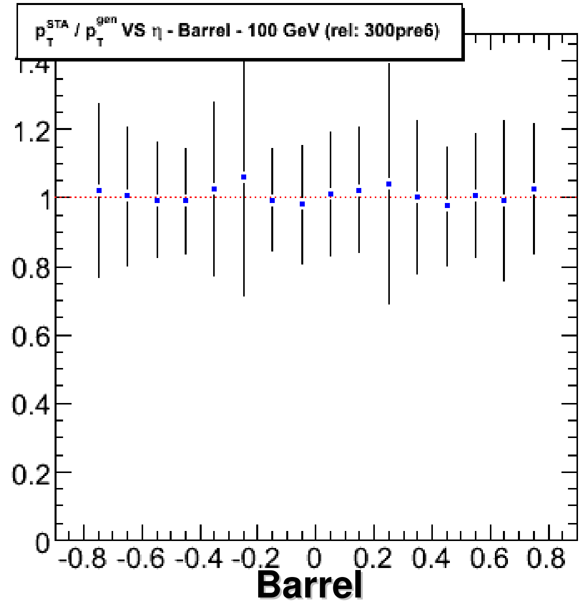
Wrong charge: 1.18%



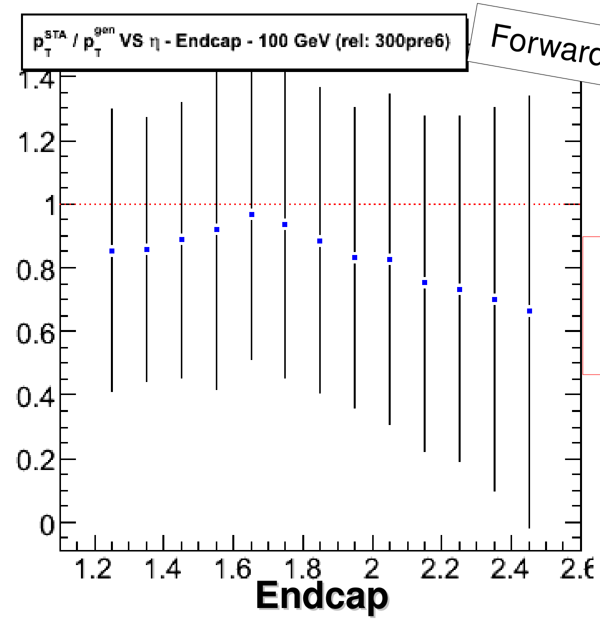


Wrong charge: 2.96%

p_T^{sta}/p_T^{gen} vs η – 300pre6 (100 GeV)



Wrong charge: 2.22%



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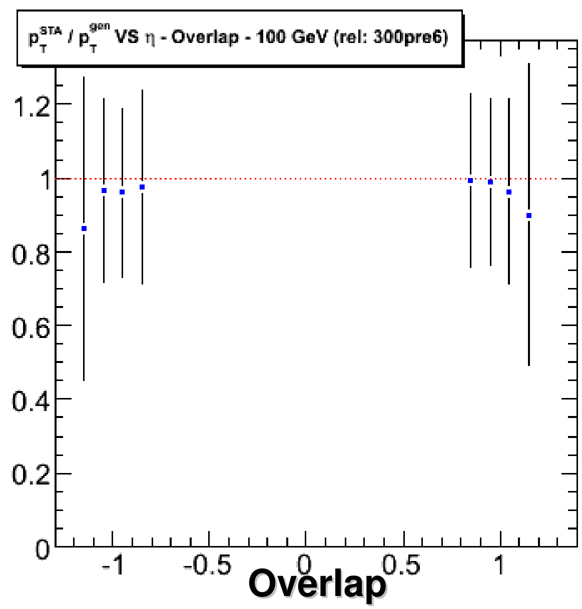

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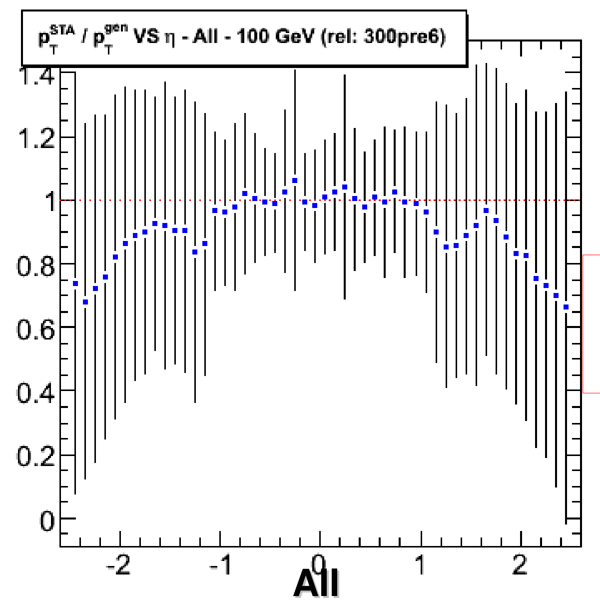
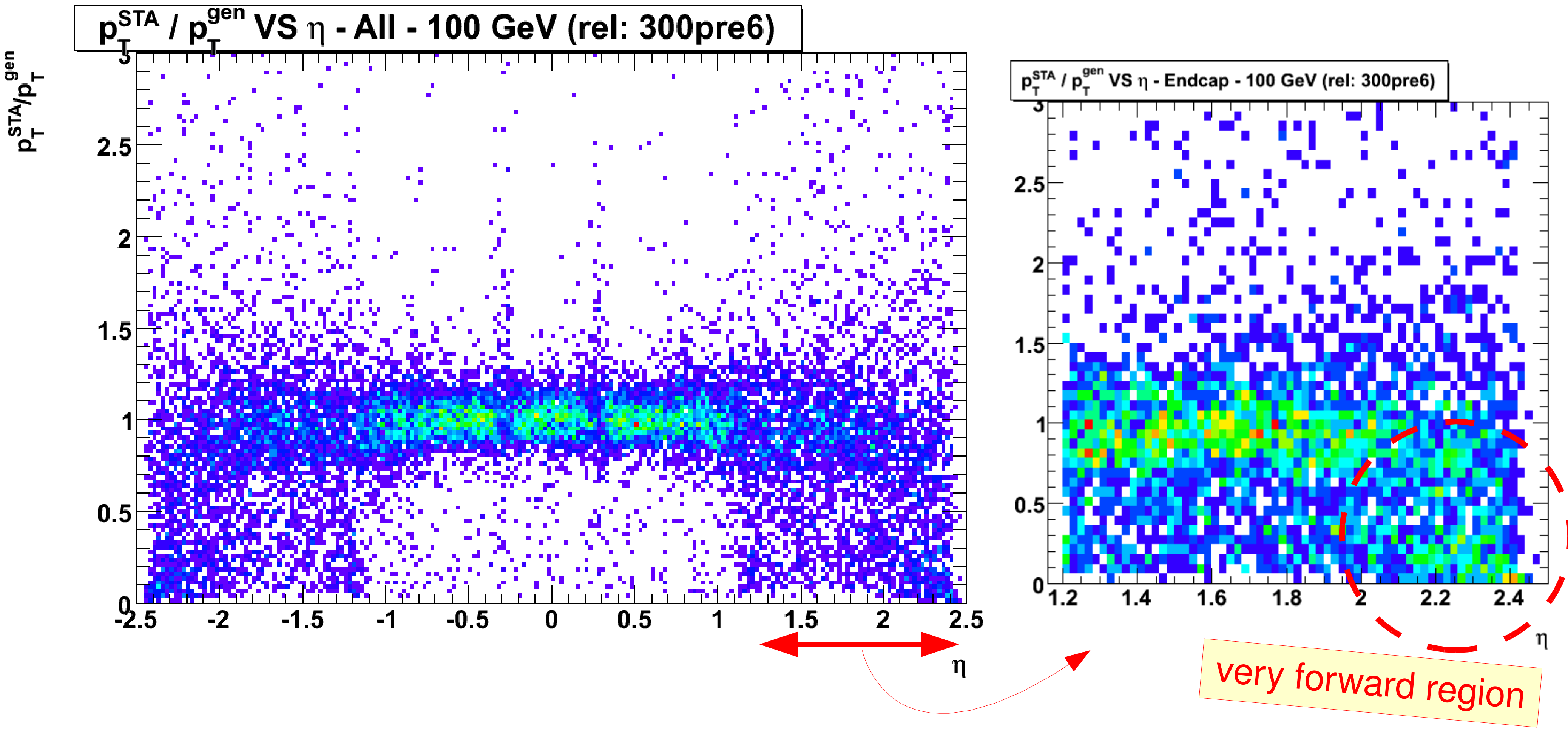


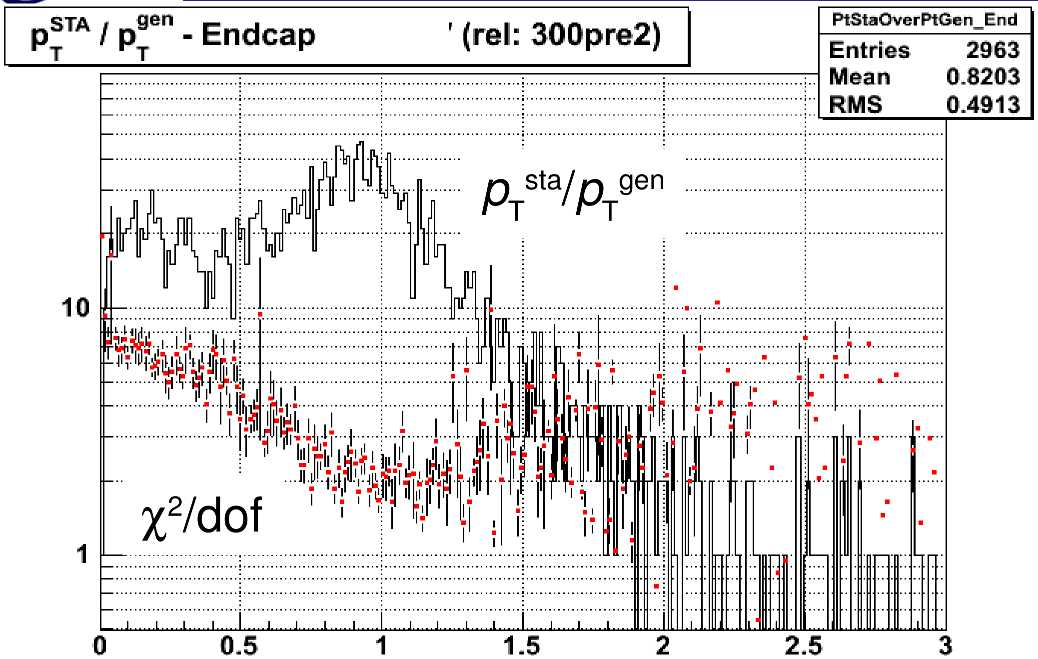
Wrong charge: 11.75%

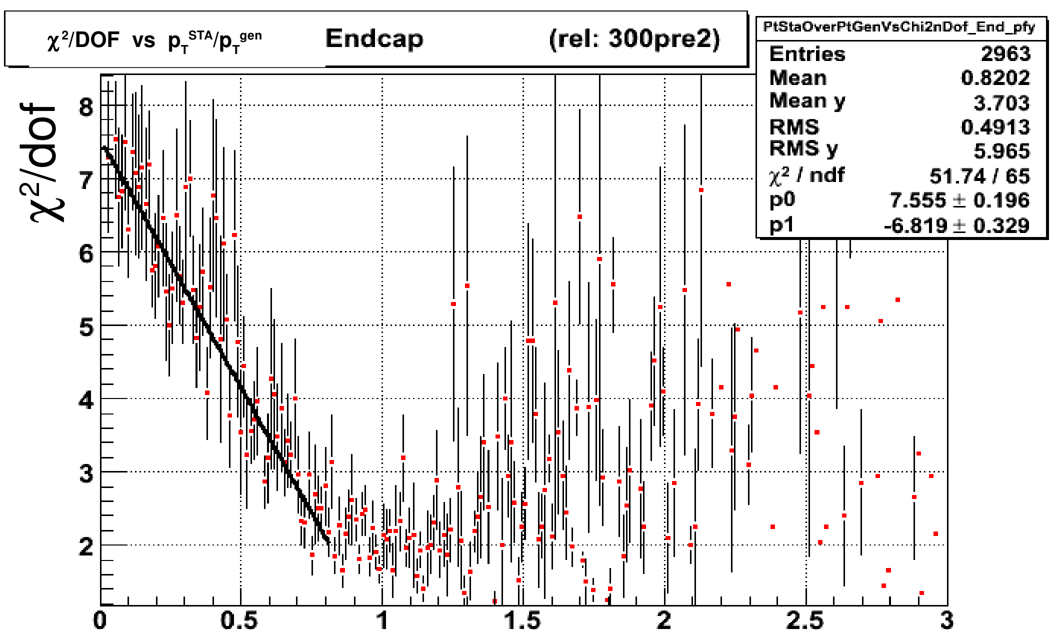
p_T^{sta}/p_T^{gen} vs η – 300pre6 (100 GeV)

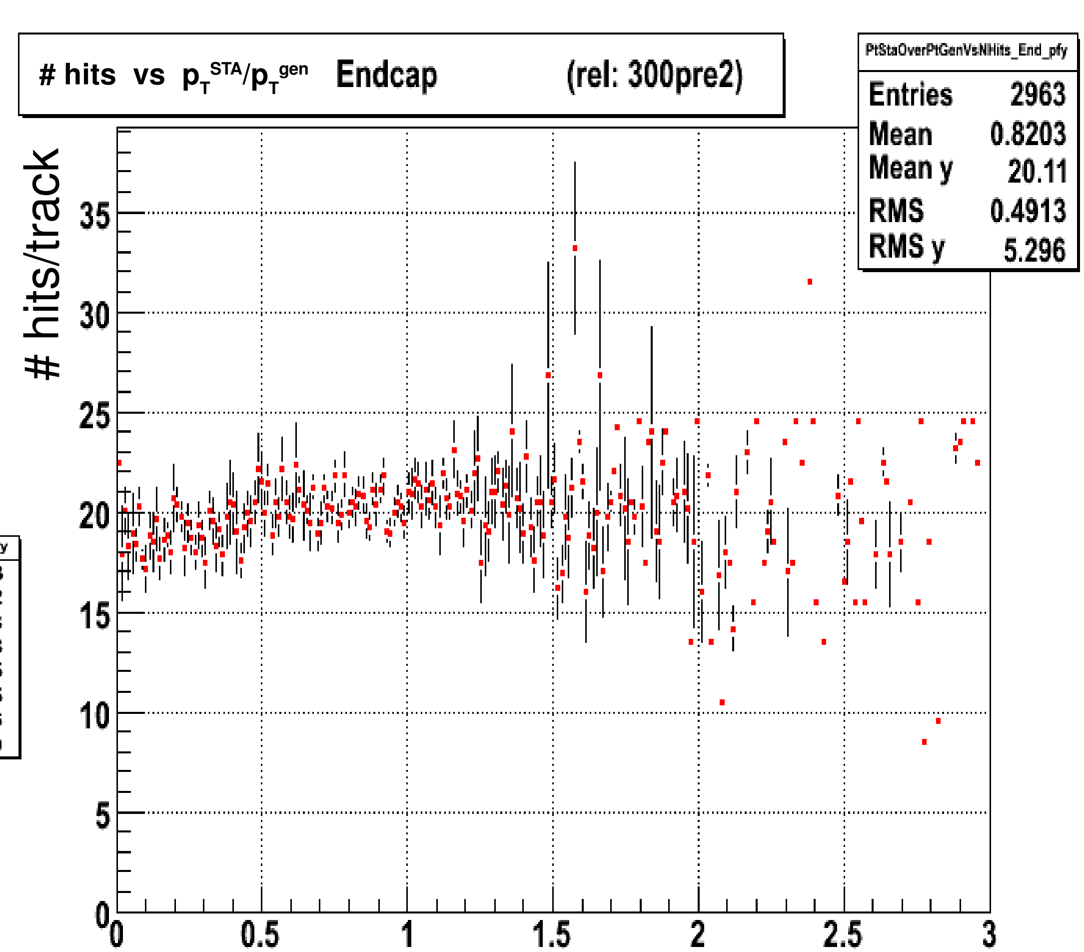


Track χ^2 in Endcaps (100 GeV)

CMSSW_3_0_0_pre2

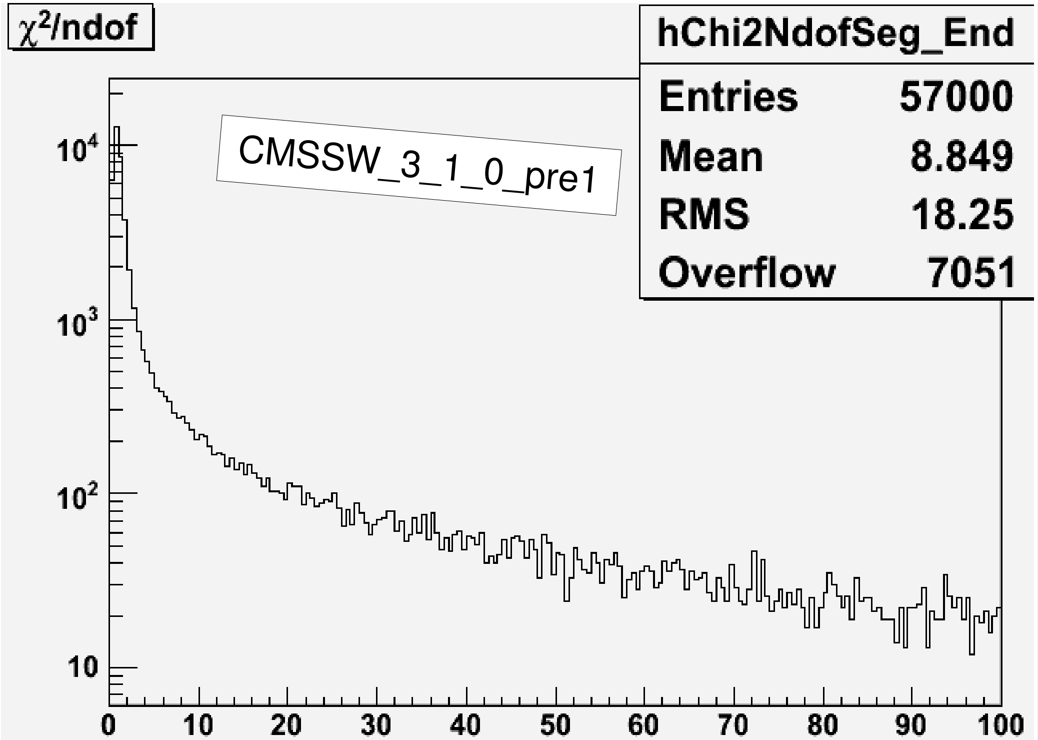


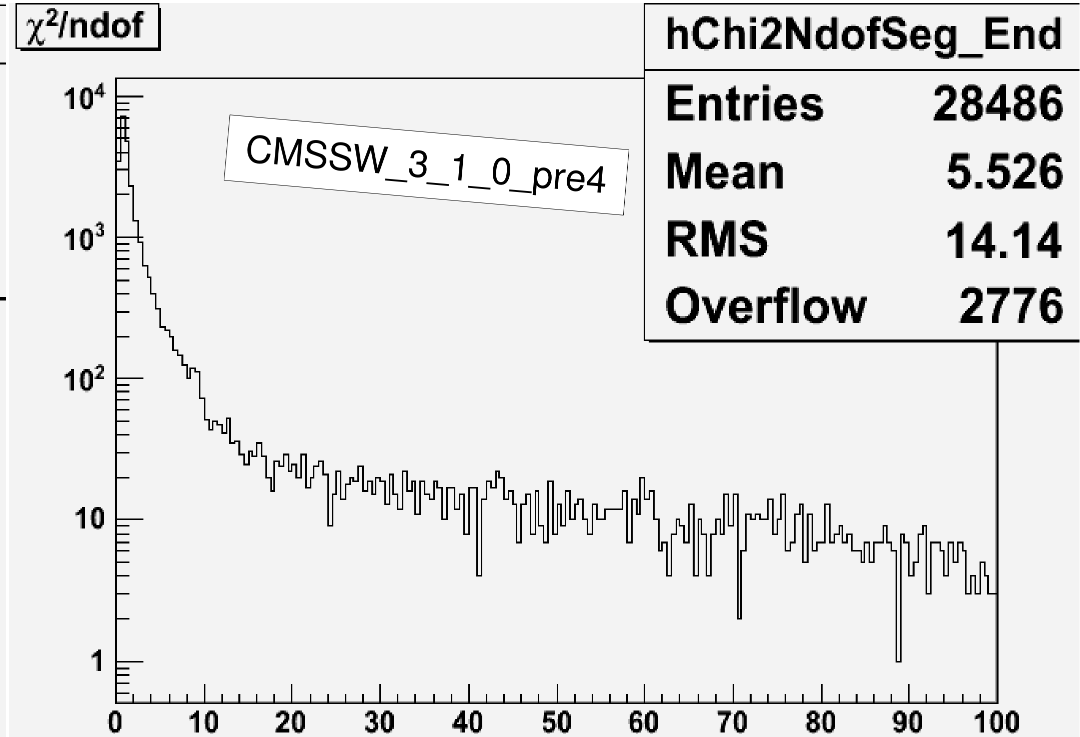




R. Bellan

Segment χ^2 in Endcaps (100 GeV)





R. Bellan

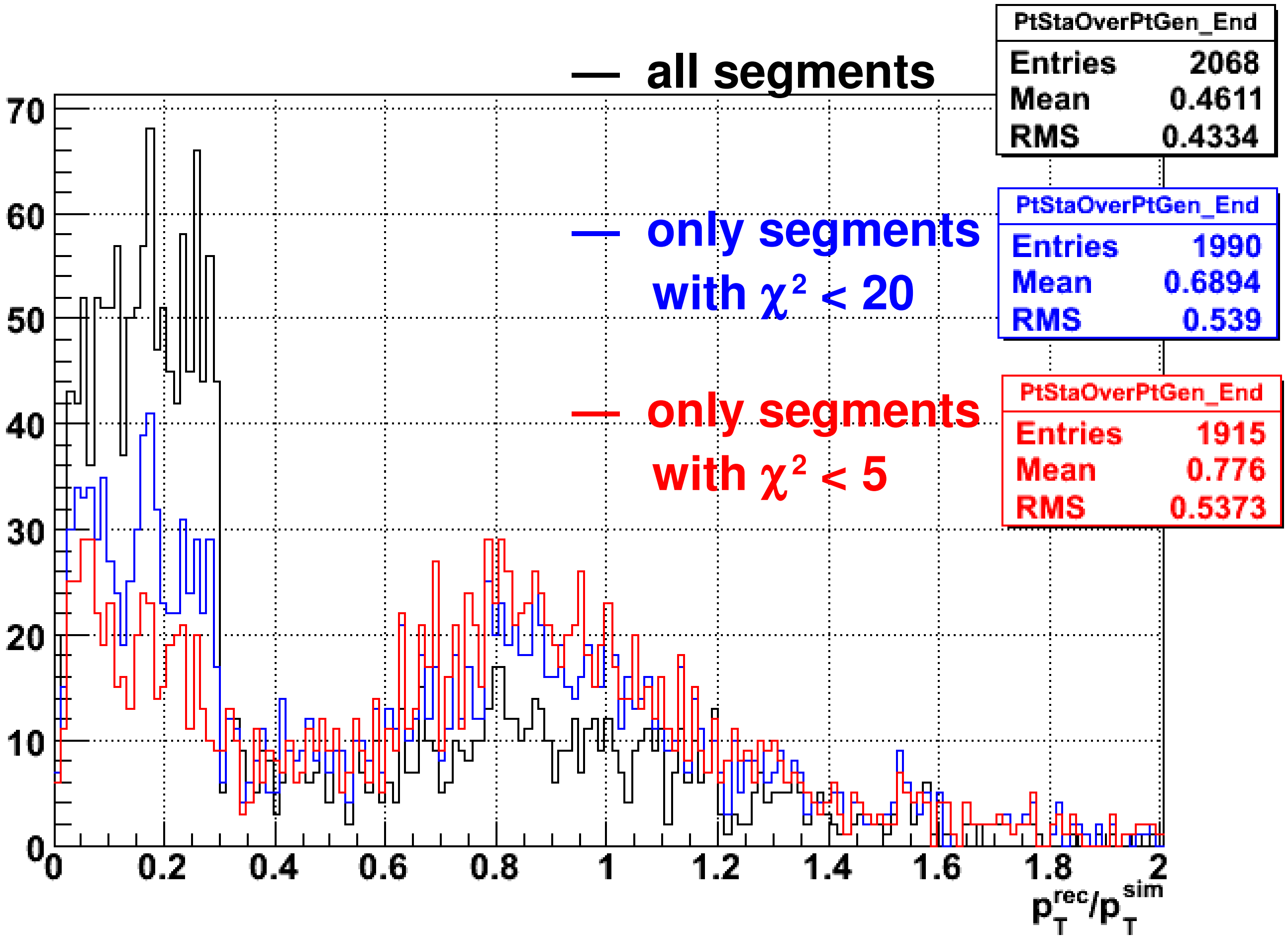
# of segments: 57000	# of segments: 28486
# of segments with χ^2/ndof < 0.1 → 1677 (~ 3%)	# of segment with χ^2/ndof < 0.1 → 895 (~ 3%)
# of segments with χ^2/ndof > 100 → 7051 (~ 12%)	# of segment with χ^2/ndof > 100 → 2776 (~ 10%)

All the segments
(not necessarily belonging to tracks!)

⇒ Anyway, we can try to get rid of them and see what happens...

χ^2 cuts on segments

Only events with at least 1 muon in the Endcaps having $p_T^{STA} / p_T^{GEN} < 0.3$



R. Bellan

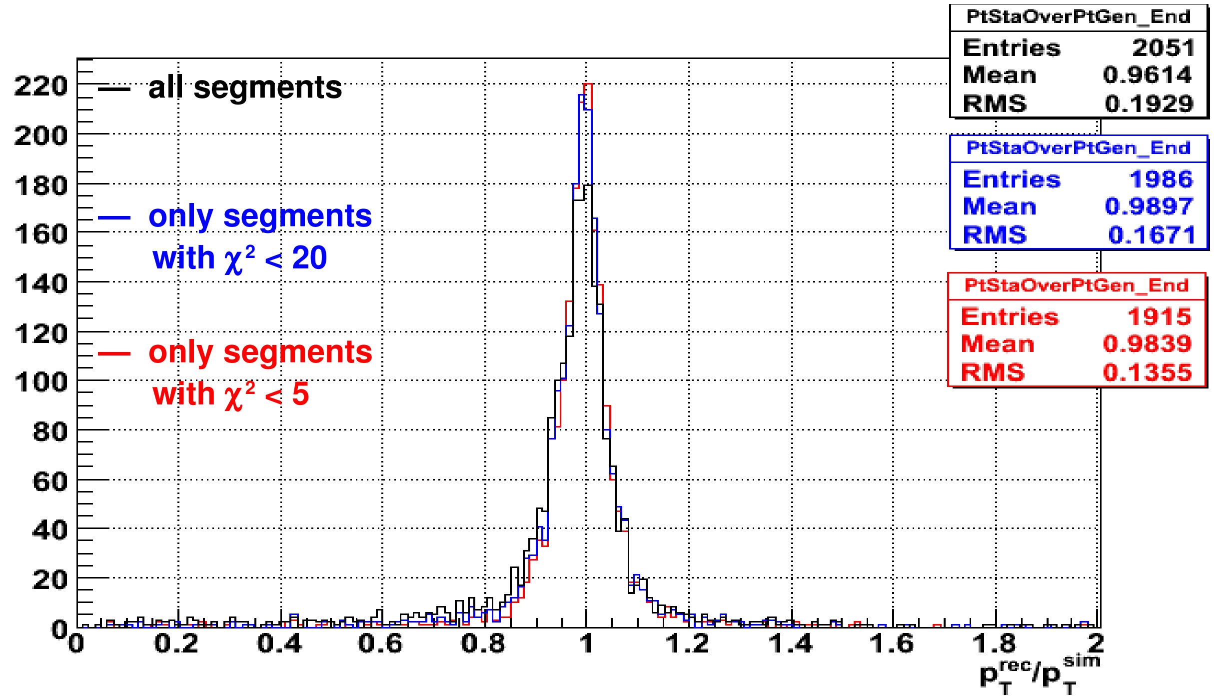
N. of muons

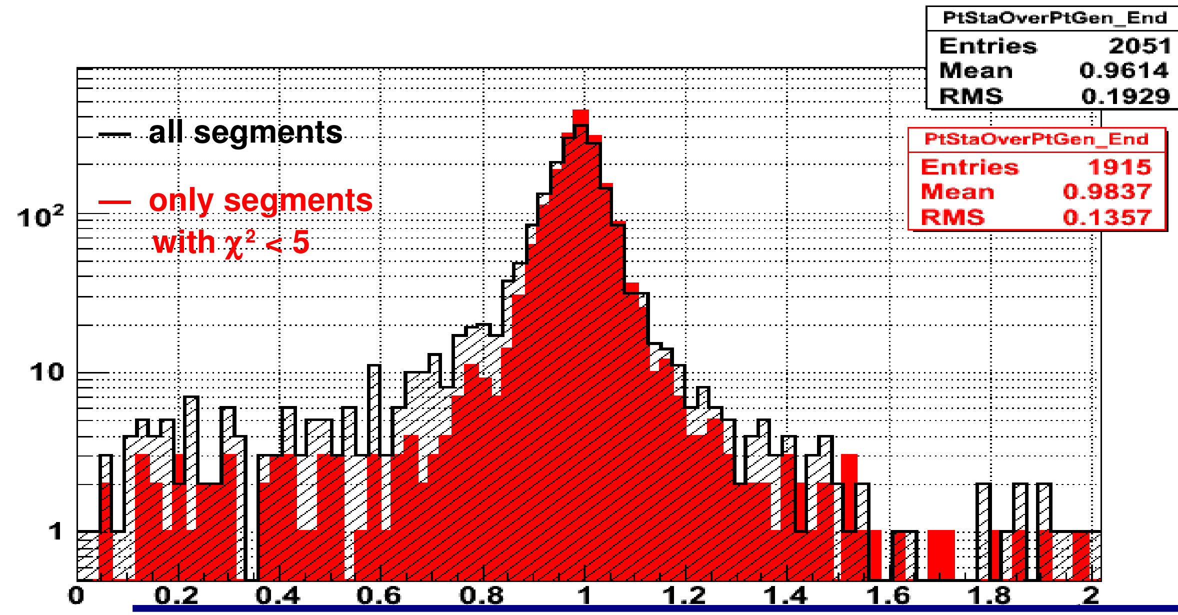
p_T^{STA}/p_T^{GEN} = 0÷2 1982
p_T^{STA}/p_T^{GEN} = 0÷0.5 1301 → 66%
charge flip 30%

p_T^{STA}/p_T^{GEN} = 0÷2 1875
p_T^{STA}/p_T^{GEN} = 0÷0.5 820 → 44%
charge flip 27%

p_T^{STA}/p_T^{GEN} = 0÷2 1842
p_T^{STA}/p_T^{GEN} = 0÷0.5 596 → 32%
charge flip 25%

Effect of χ^2 cuts on global reconstruction





	N. of muons
# p_T^{STA}/p_T^{GEN} = 0÷2	2032
# p_T^{STA}/p_T^{GEN} = 0÷0.5	189 → 9.3%
# charge flip	2.2%
# p_T^{STA}/p_T^{GEN} = 0÷2	1971 (3% loss)
# p_T^{STA}/p_T^{GEN} = 0÷0.5	93 → 4.7%
# charge flip	1.3%
# p_T^{STA}/p_T^{GEN} = 0÷2	1898 (7% loss)
# p_T^{STA}/p_T^{GEN} = 0÷0.5	76 → 4.0%
# charge flip	1.6%

Possible improvements (work ongoing...)

- Final goal → improve global track resolution
  (χ^2 cuts improve both STA and global tracks resolution)
  → keep the highest efficiency
  (χ^2 cuts cause drops in efficiency)

- Possible strategies:
  - "split" STA track collections (or simply add a *"quality bit"*):
    - "*golden* tracks" (with better resolution) in a separate collection
    - usual tracks (with higher efficiency) used only for matching
  - keep the STA collection as it is and postpone the segment skimming to global reconstruction
  - introduce *invalid* hits:
    - tight χ^2 cut: RecHit is valid (used for the fit)
    - loose χ^2 cut: RecHit is compatible with the trajectroy but invalid (added to the trajectory but *not used* for the fit)
      → possibility of stand-alone tracks *containing only* invalid RecHits: only seed information, but used for matching