NOVa
August 22, 2012

Lepton scale factors

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Overview

- Lepton scale factors (electrons and muons)
  - ID: PFlepton -> passes “tight” id requirement
  - Isolation: tight PFlepton -> passes isolation requirement
  - HLT: tight, iso PFlepton -> matched ($\Delta R<0.3$) to trigger lepton
    - Specifically for single lepton triggers
  - Samples (53xOn52x)
    - SingleElectron (2012 A+B) – 75 M events
    - SingleMu (2012 A+B) – 61 M events
    - DYJetsToLL – 30 M events
      - PU, b-tag re-weighting
- Z-mass window: 70 – 130 GeV
- Tag-and-probe cut and count efficiency
  - Tag: lepton with $p_T > 30$ GeV, passing “tight” cuts, trigger matched
  - Assume no non-Z backgrounds

Different binning used

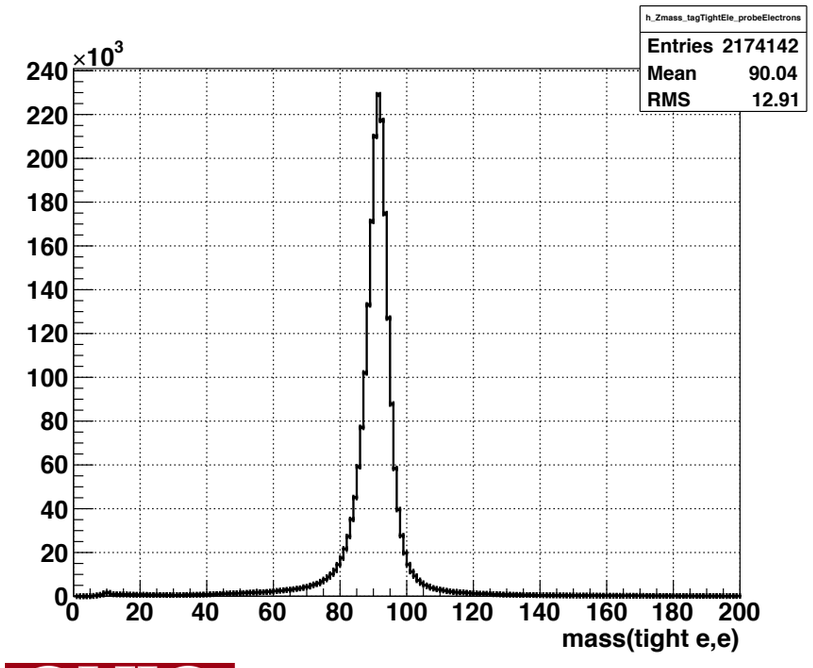
- Binning matches Muon POG
  - Eta
    - -2.4, -2.1, -1.6, -1.2, -0.9, -0.6, -0.3, -0.2, 0.2, 0.3, 0.6, 0.9, 1.2, 1.6, 2.1, 2.4
    - For now, muons only have $|\eta| < 2.1$
  - pT
    - 10, 15, 20, 25, 30, 35, 40, 50, 60, 90, 140, 500
  - numJet
    - -0.5, 0.5, 1.5, 2.5, 3.5, 4.5, 5.5, 10.5
  - numTag
    - -0.5, 0.5, 1.5, 2.5, 3.5, 4.5, 10.5
  - numPV
    - -0.5, 2.5, 4.5, 6.5, 8.5, 10.5, 12.5, 14.5, 16.5, 18.5, 20.5, 22.5, 24.5, 26.5, 28.5, 30.5, 40.5

Tag-and-probe

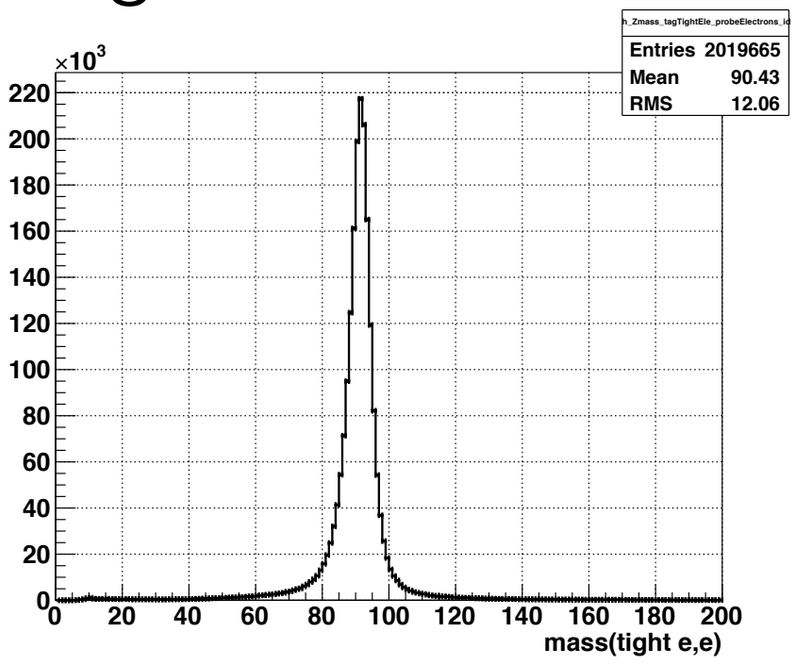
- The tag and the probe are required to have
  - Invariant mass within 70 and 130 GeV
  - Opposite charge
- Negligible non-Z backgrounds in inclusive sample

SingleElectron data

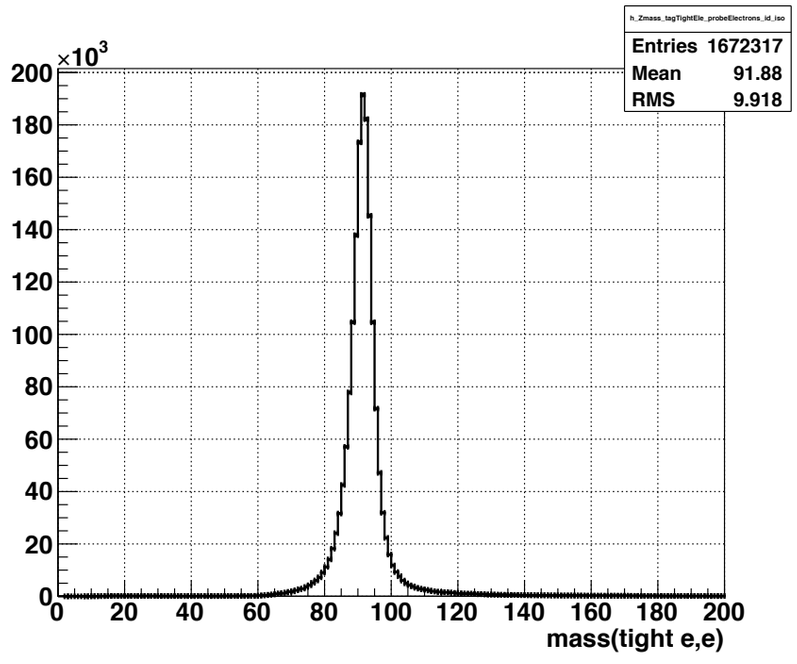
Probe: PFelectron



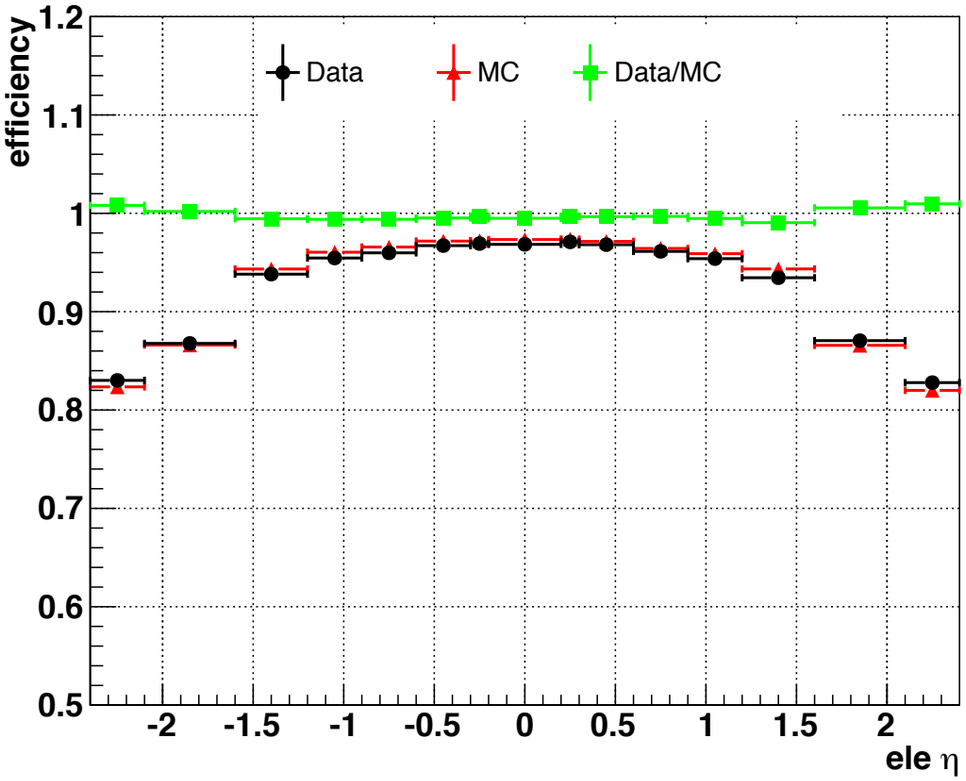
Probe: tight PFelectron

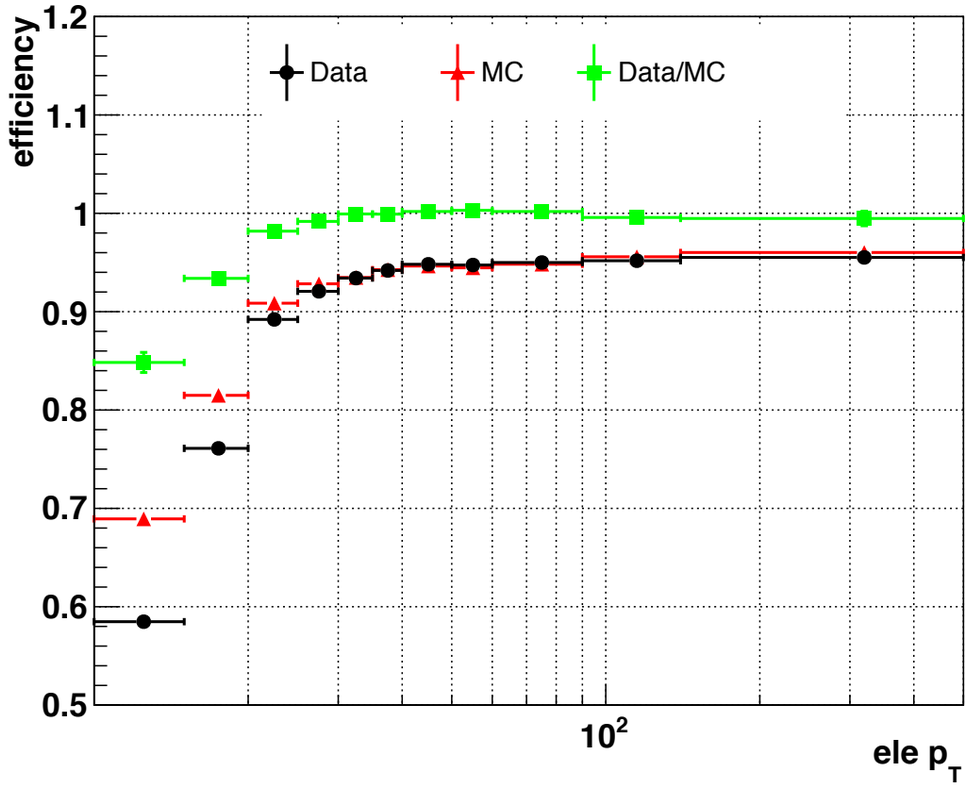


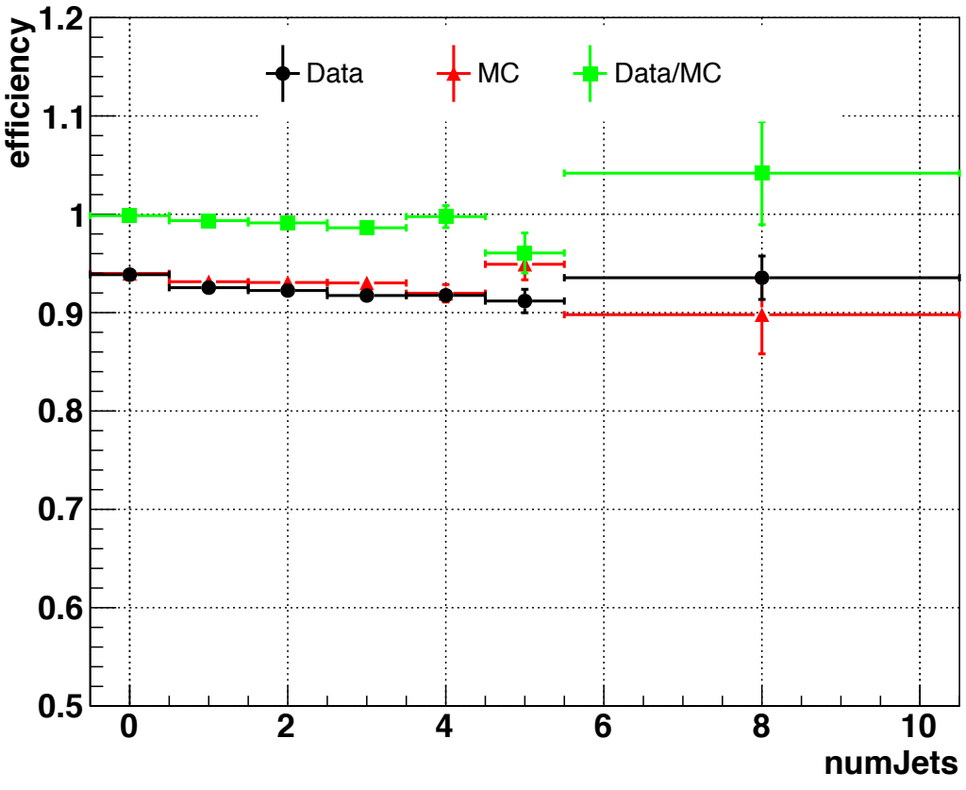
Probe: tight, iso PFelectron

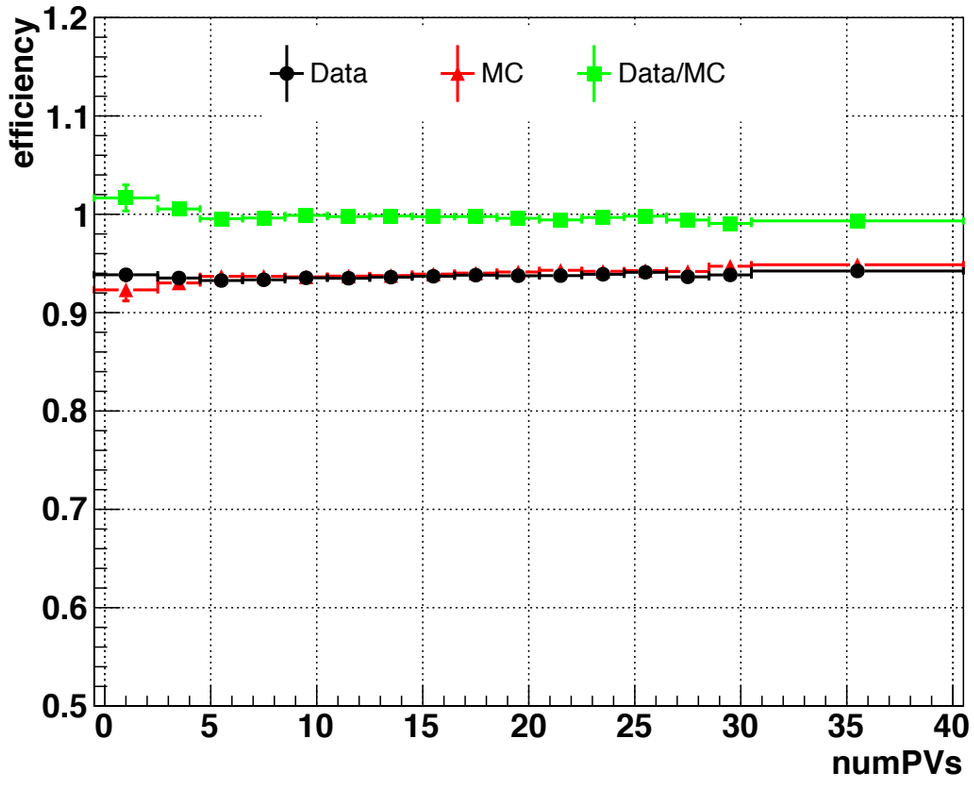


Electron: id









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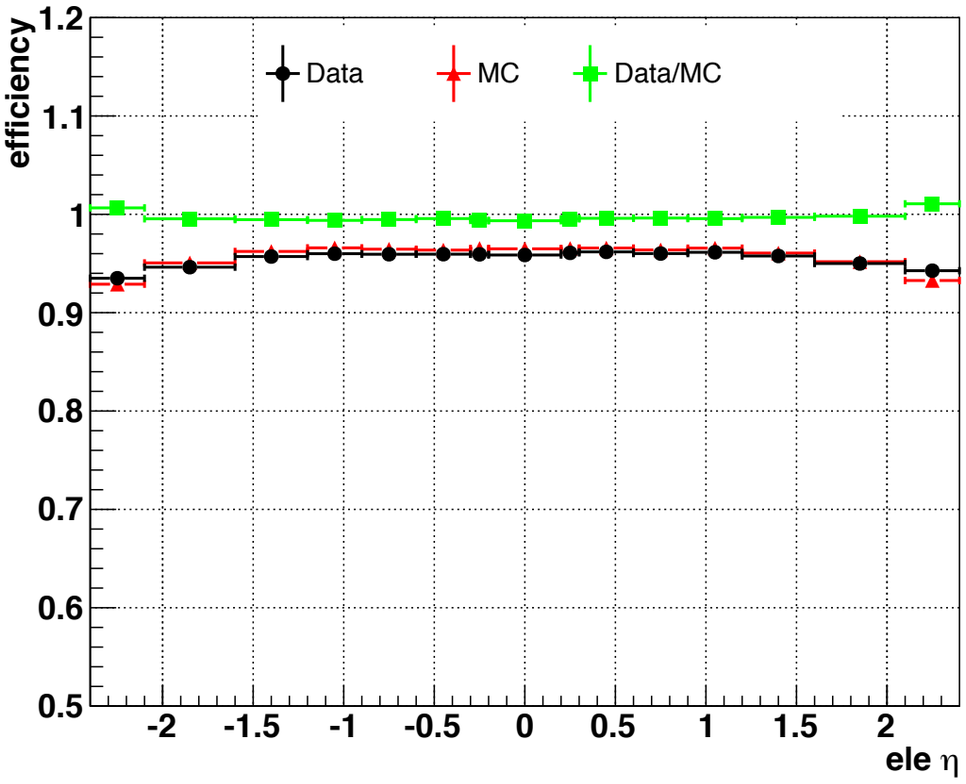
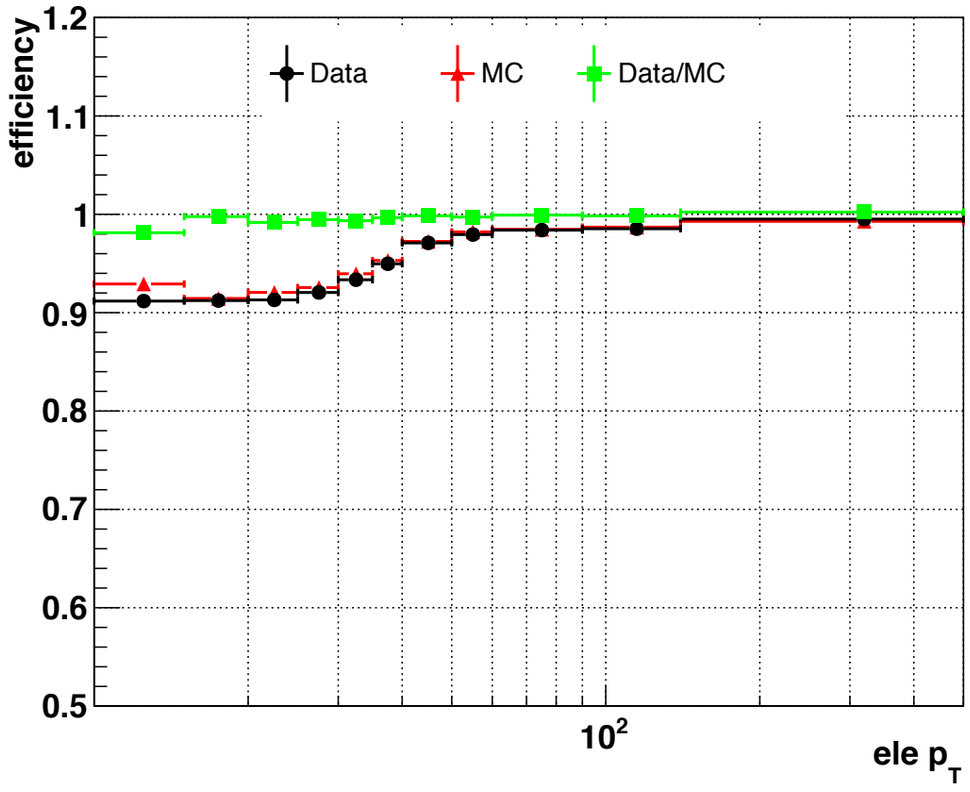
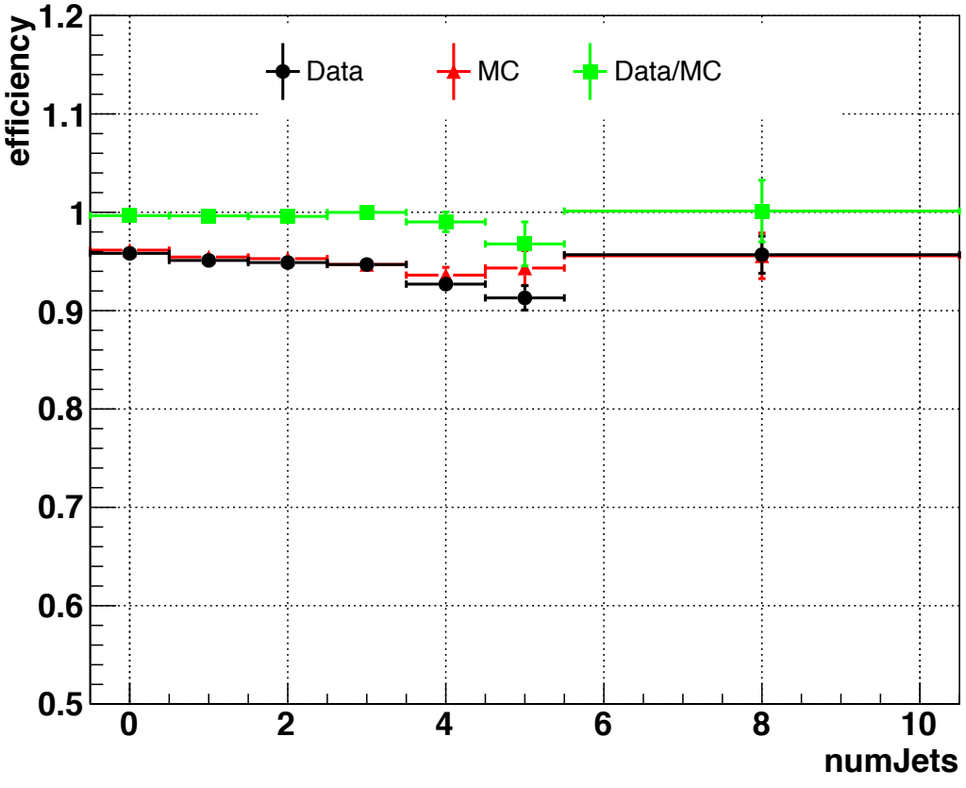
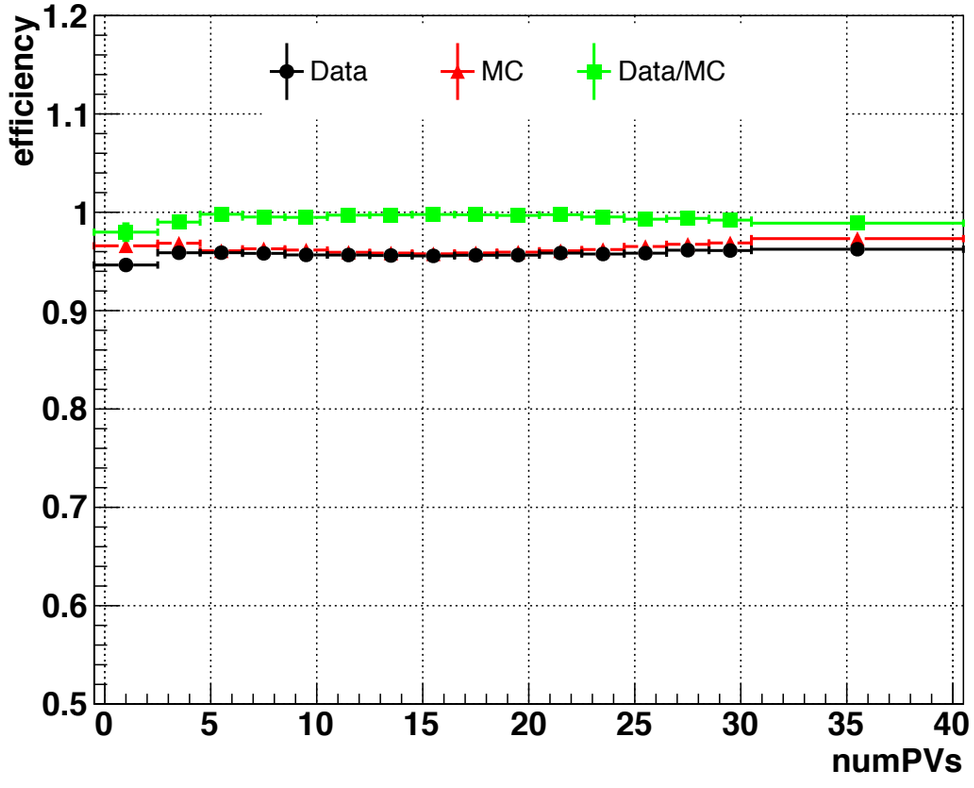
Electron: iso









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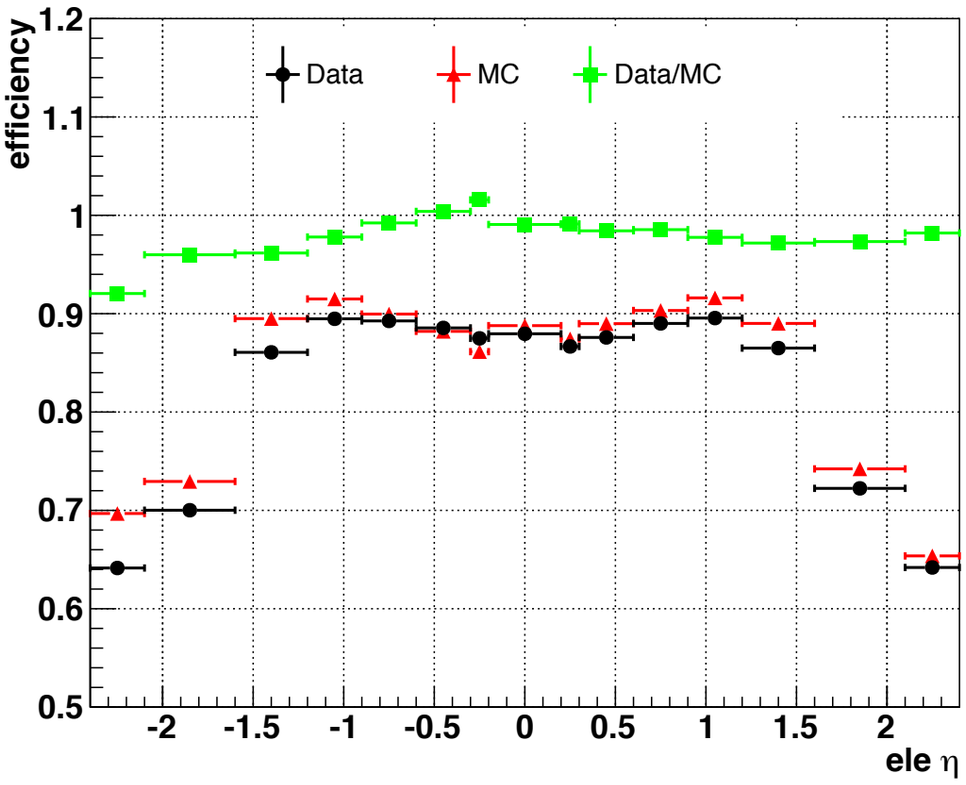
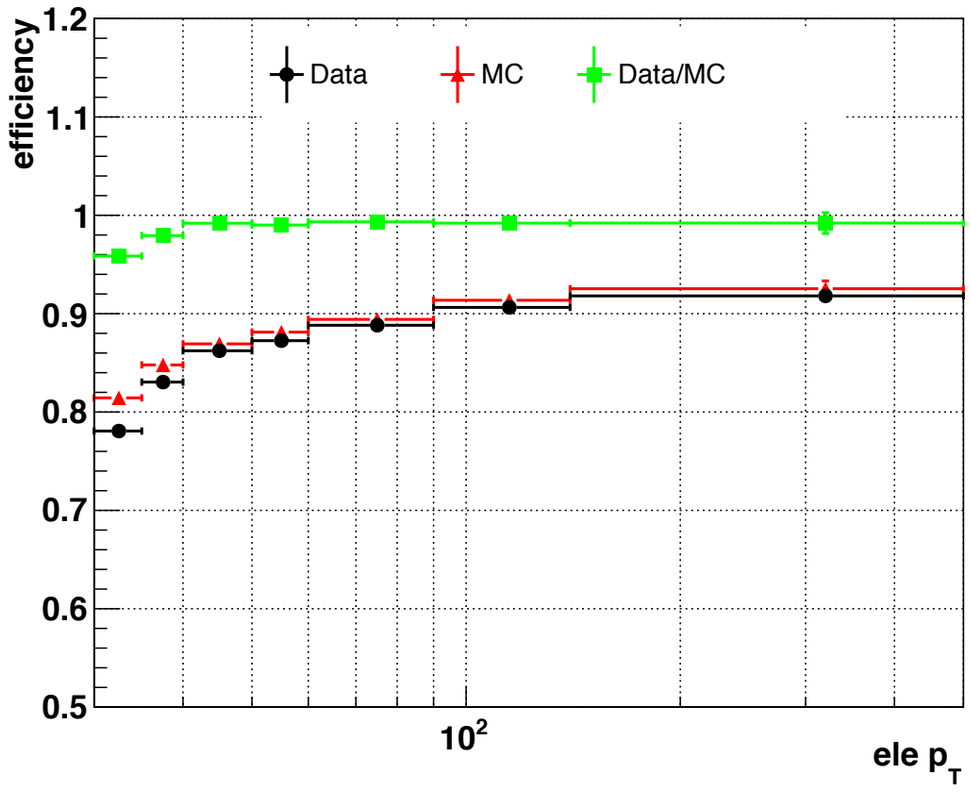
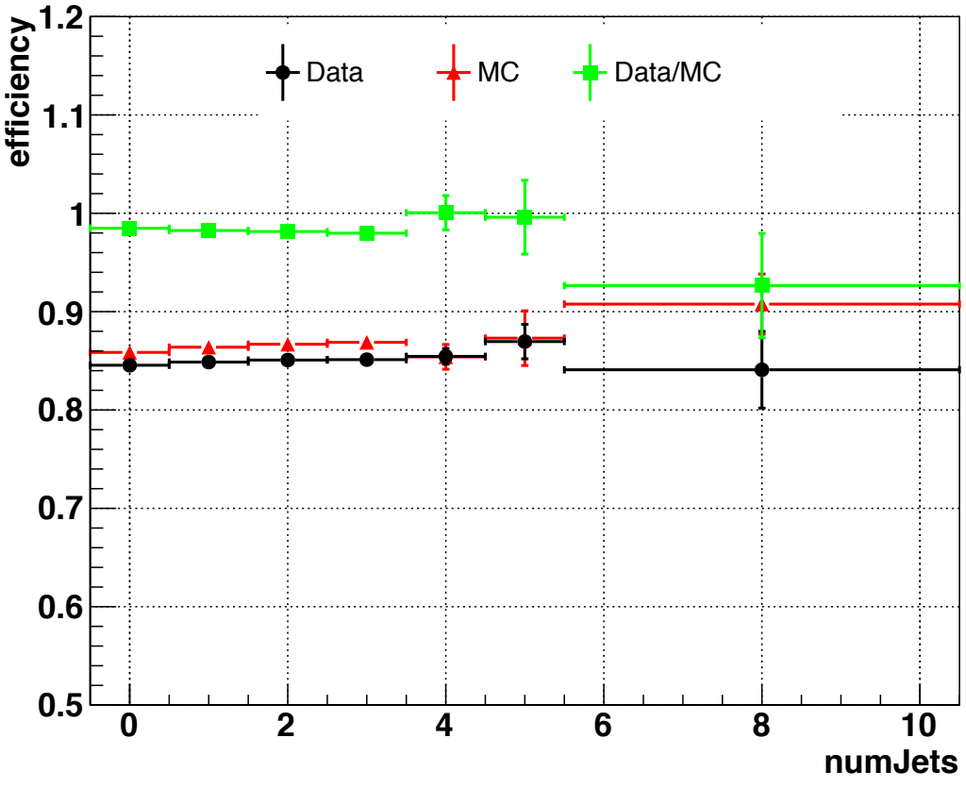
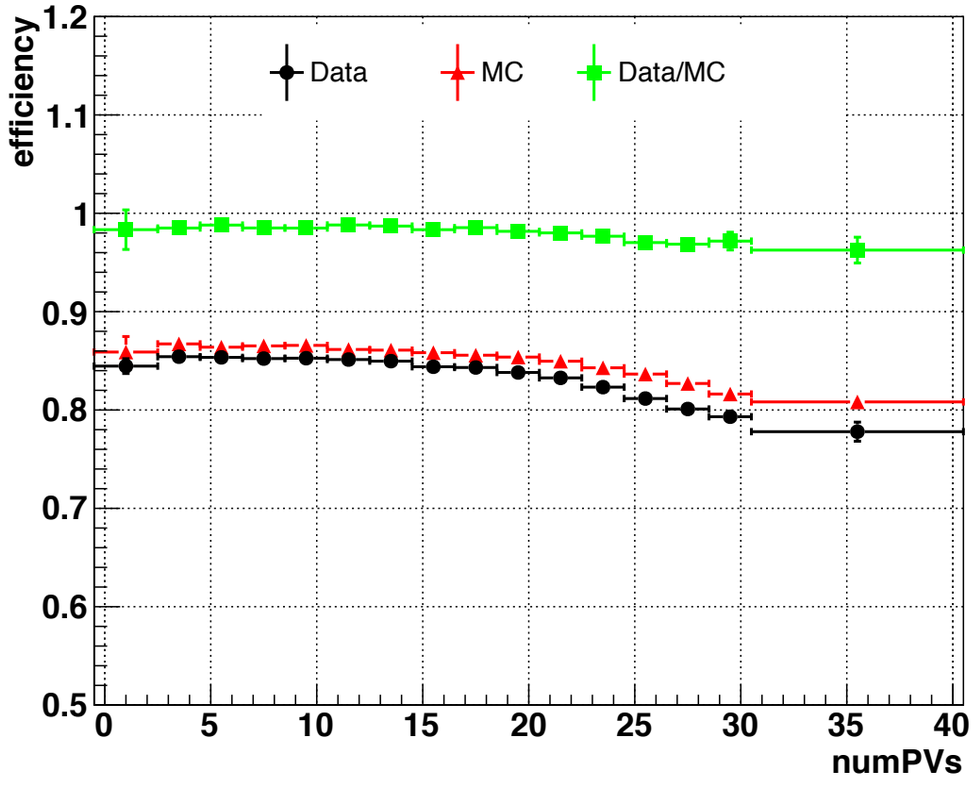
Electron: HLT









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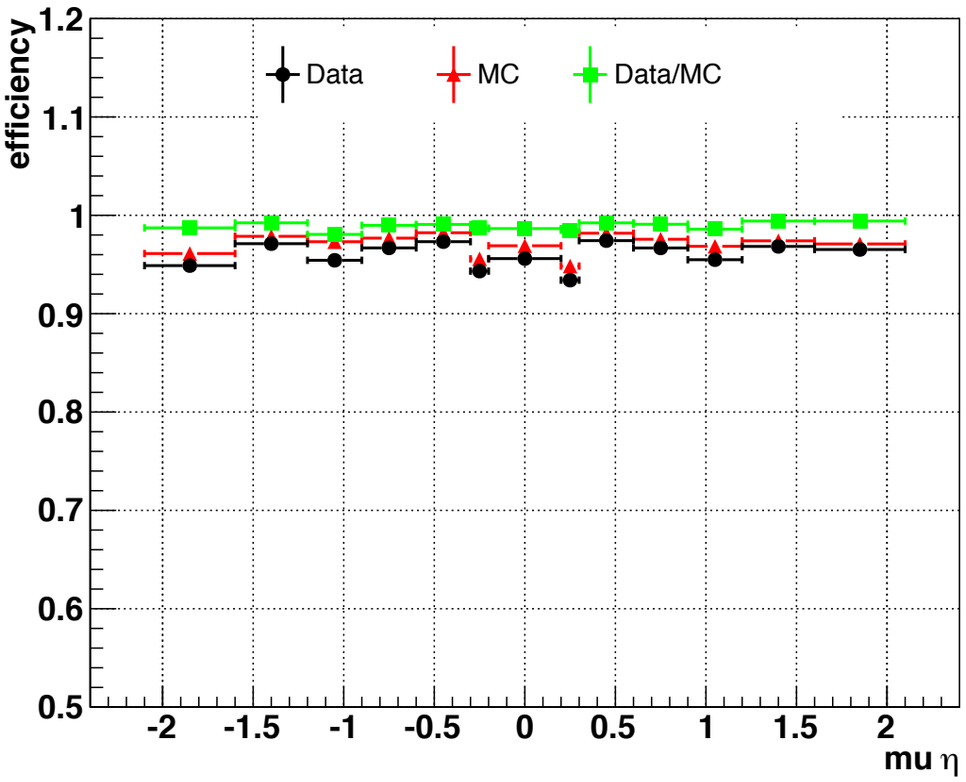
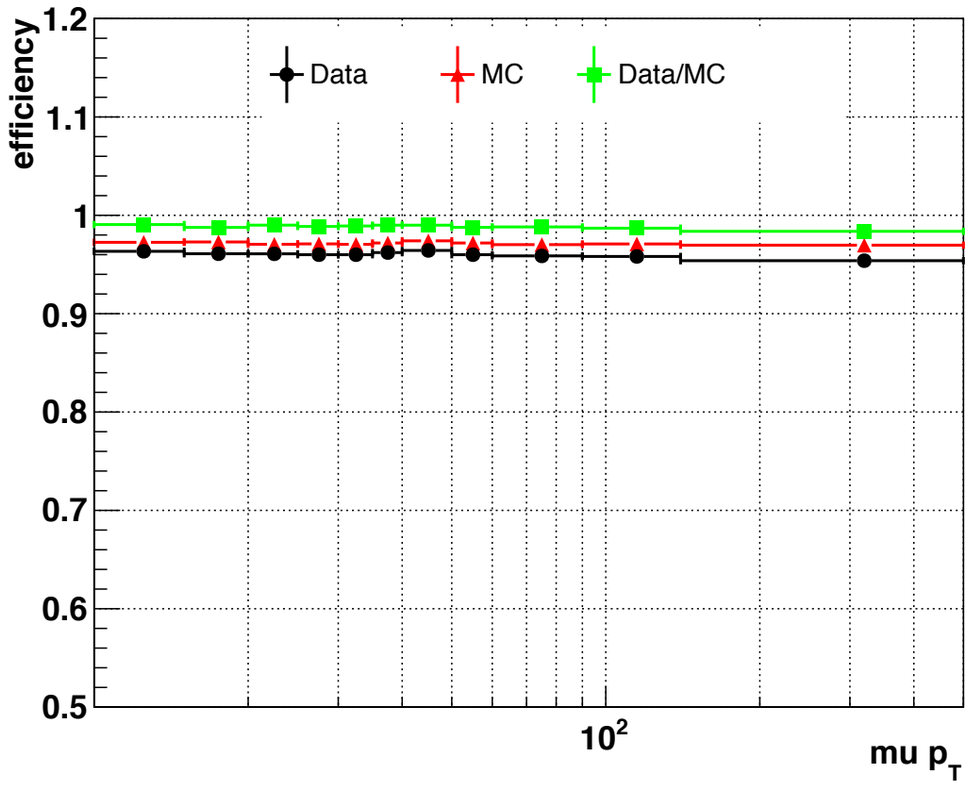
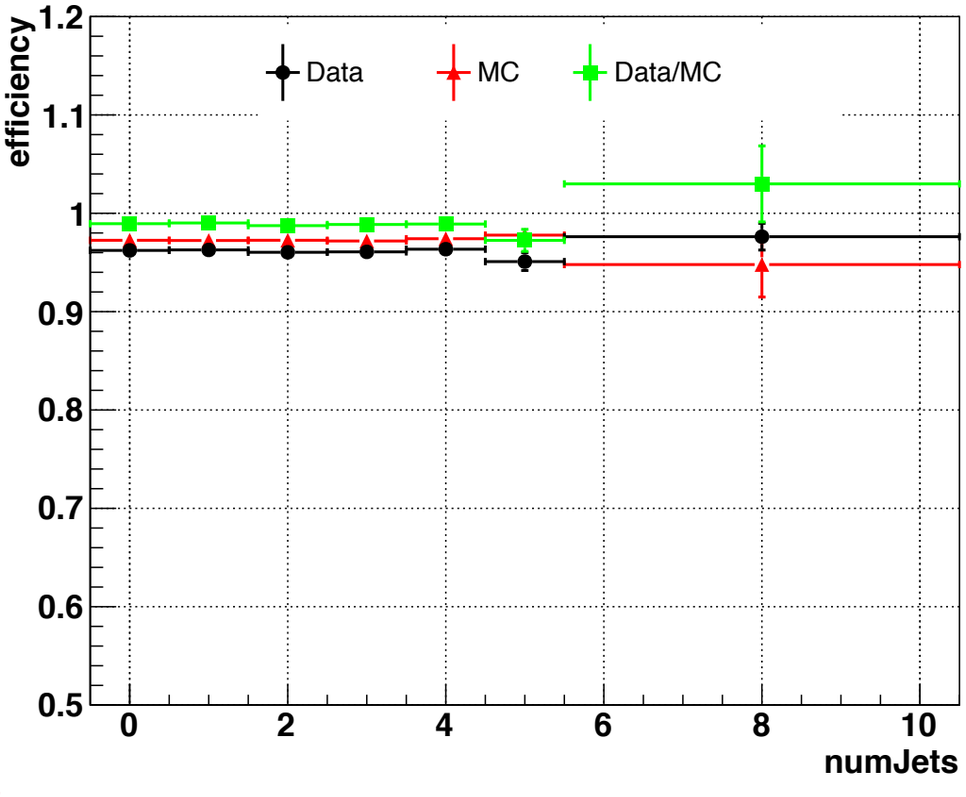
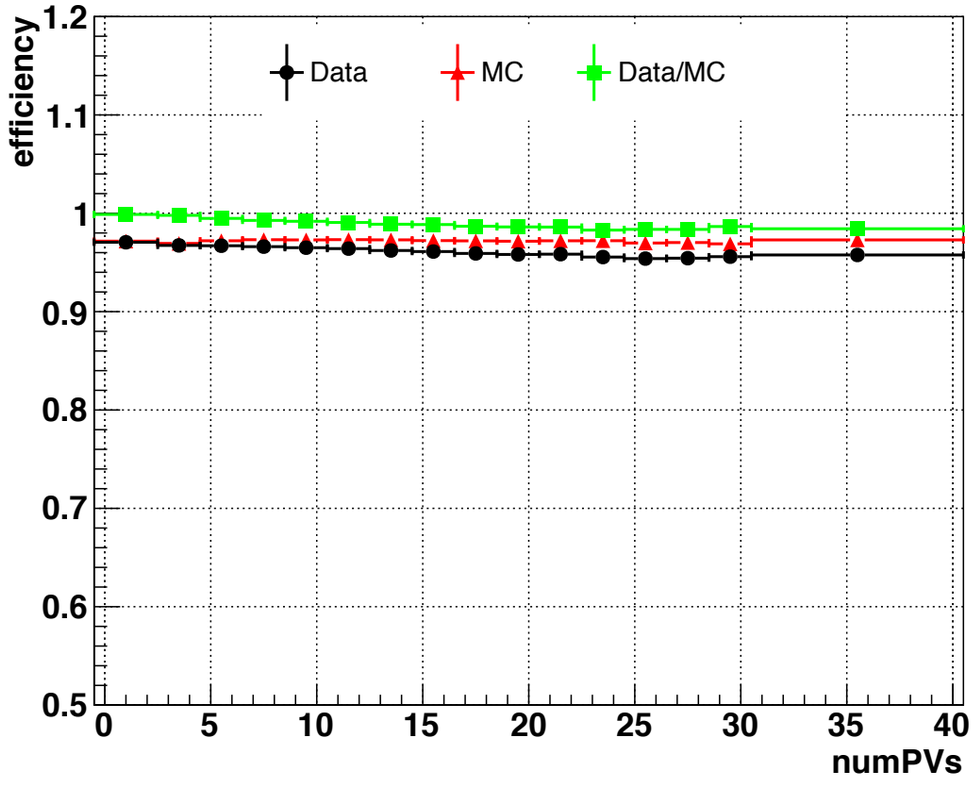
Muon: id









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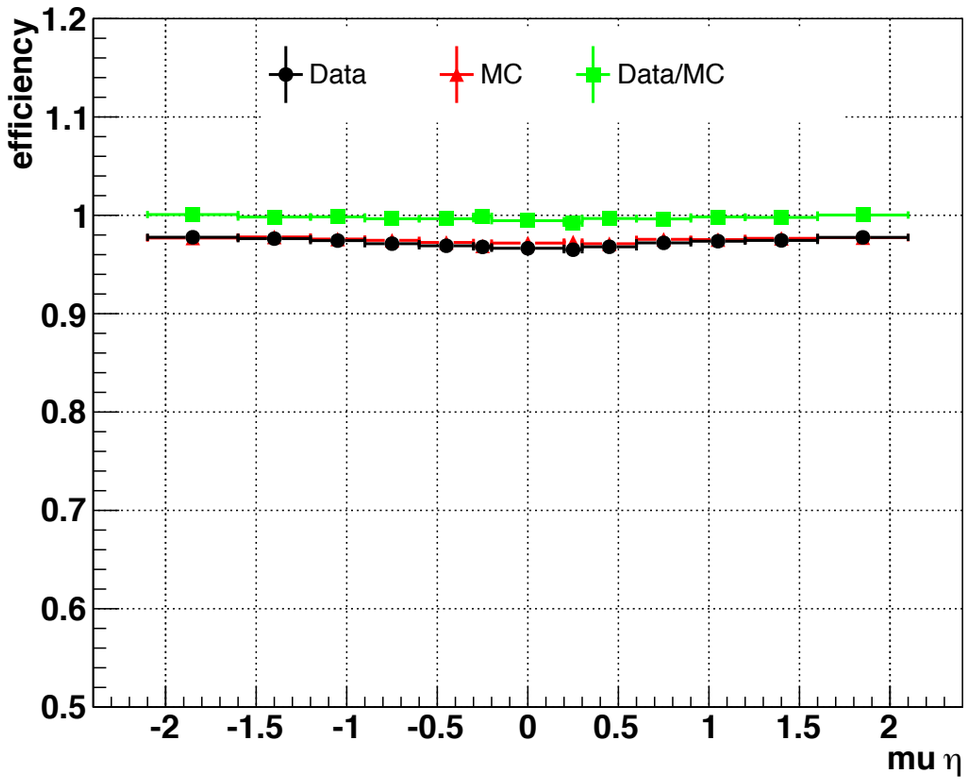
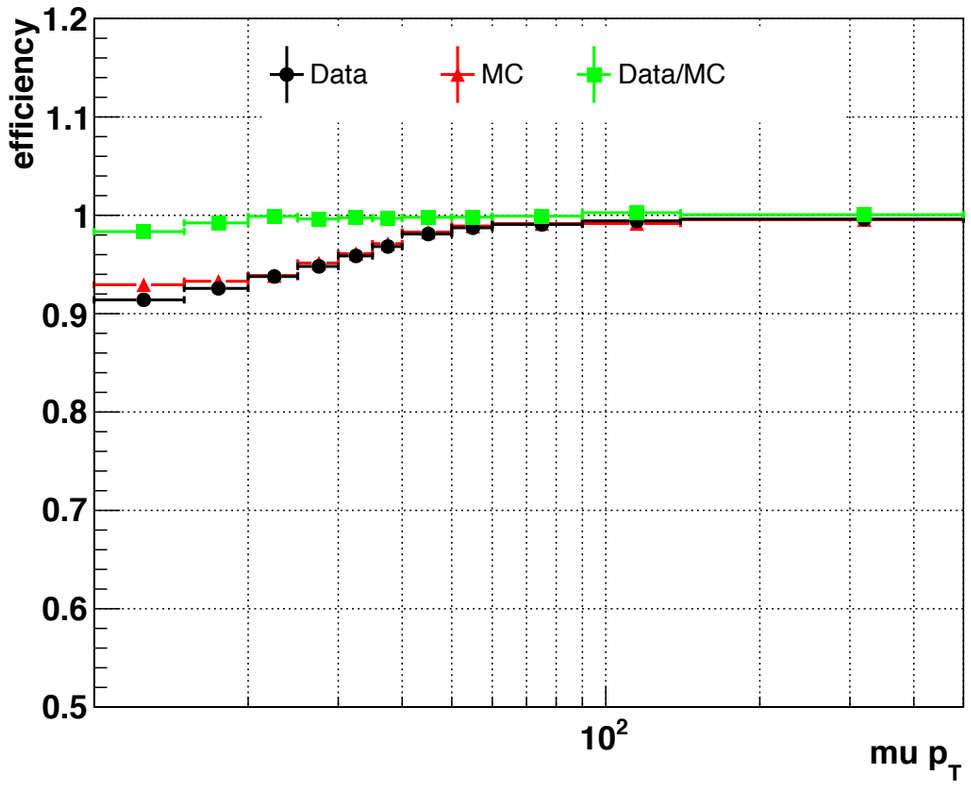
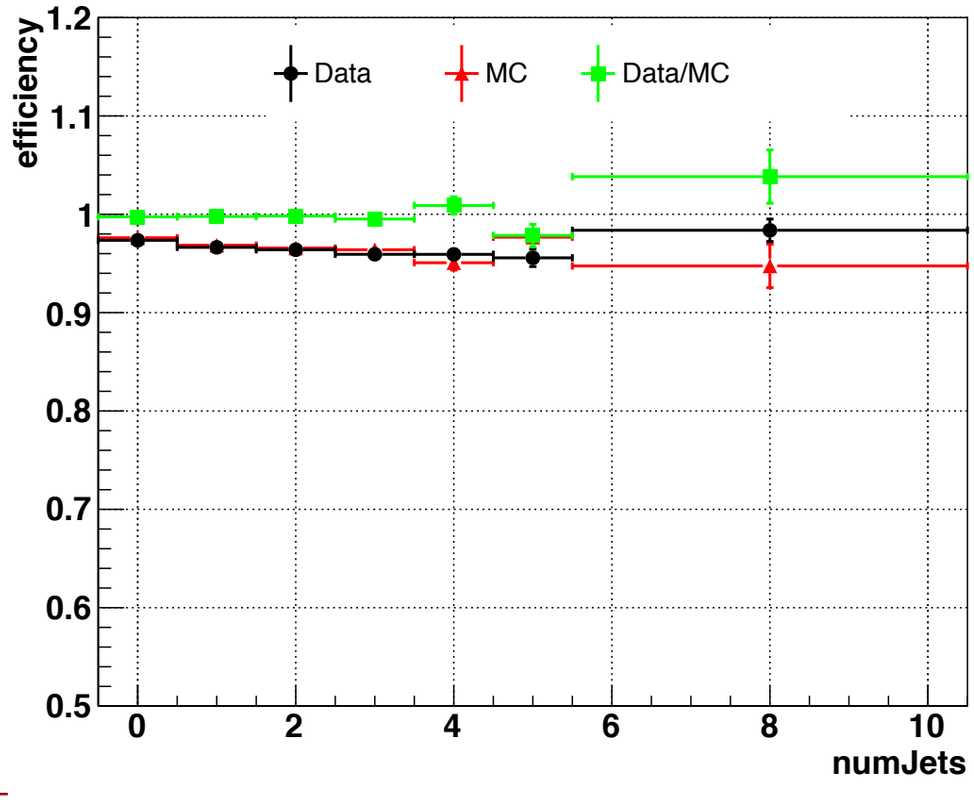
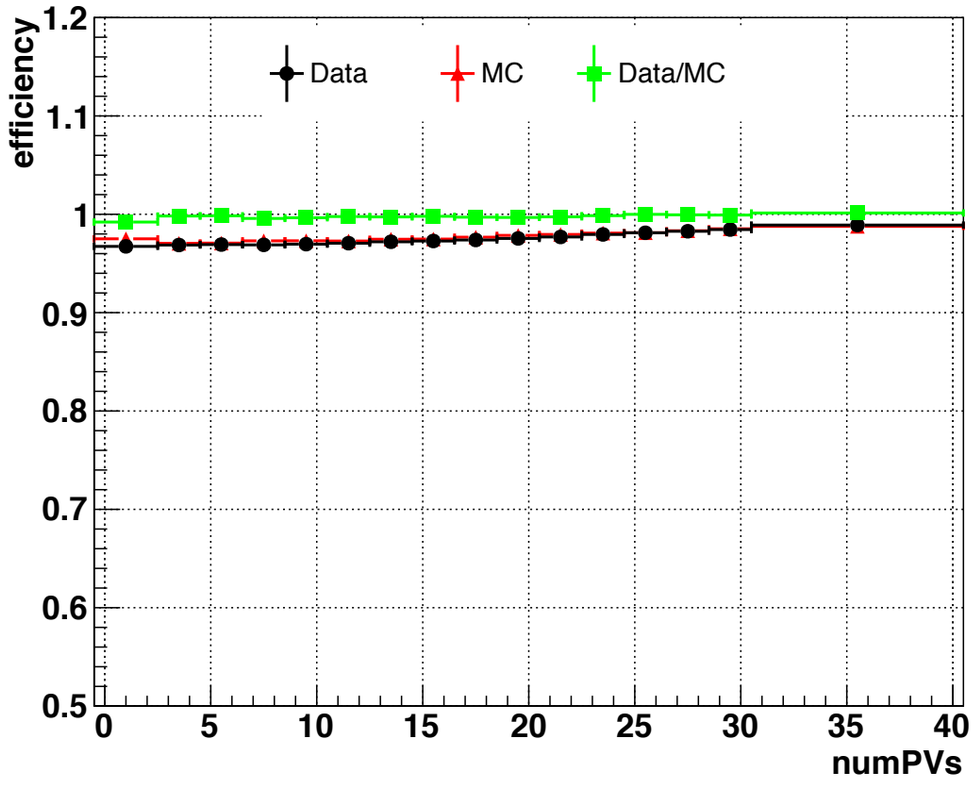
Muon: iso









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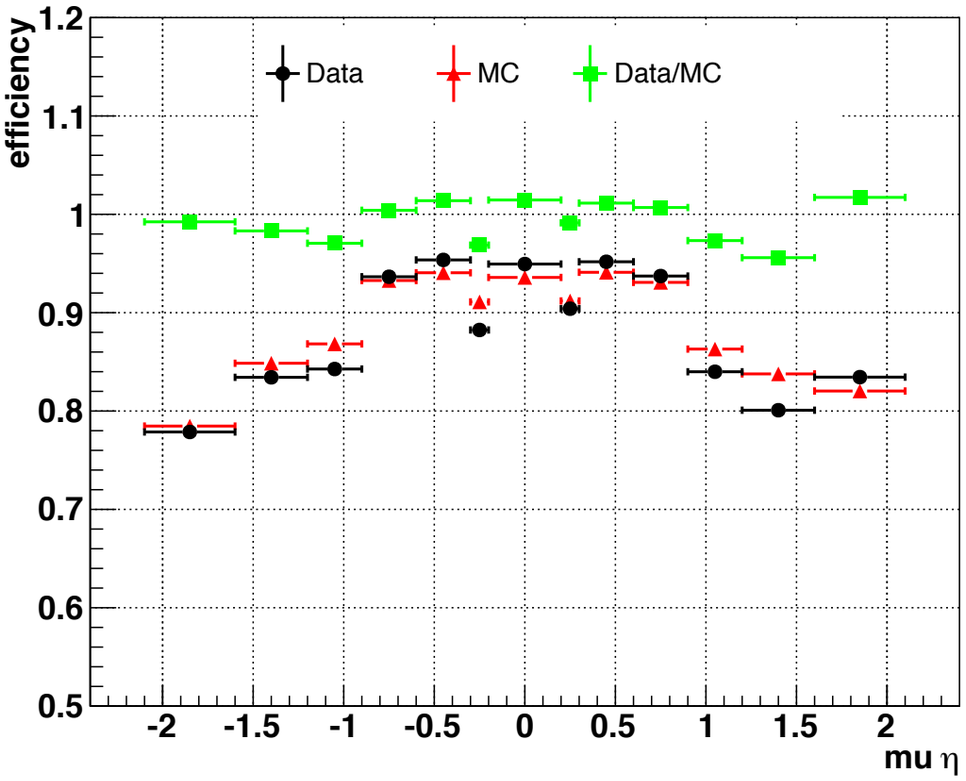
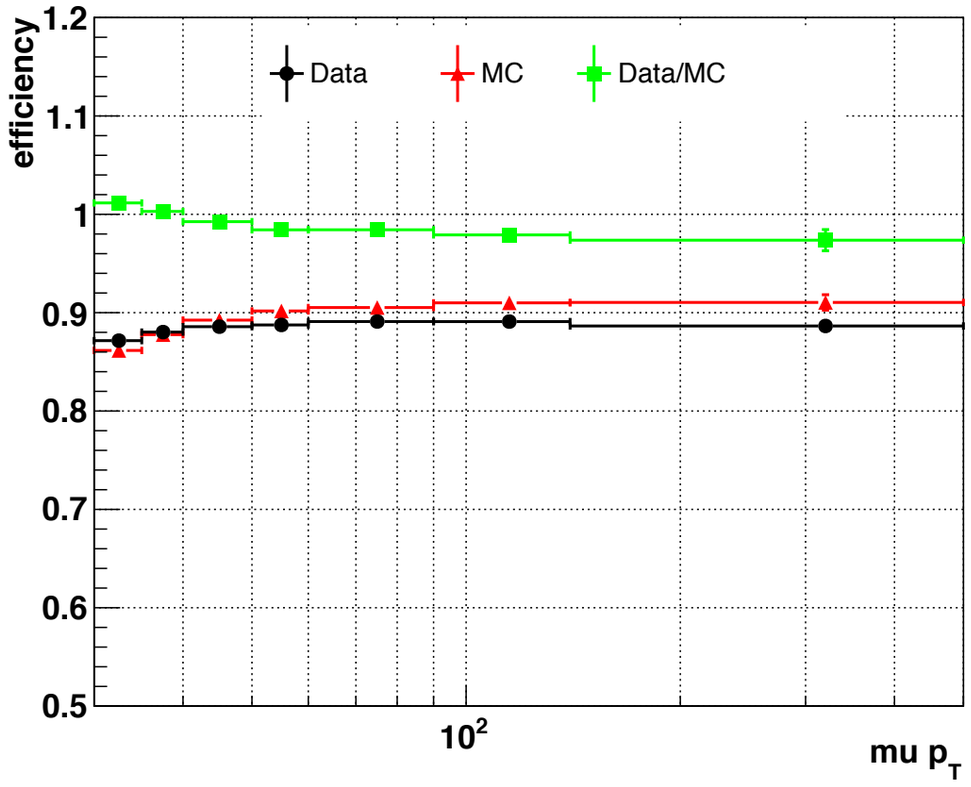
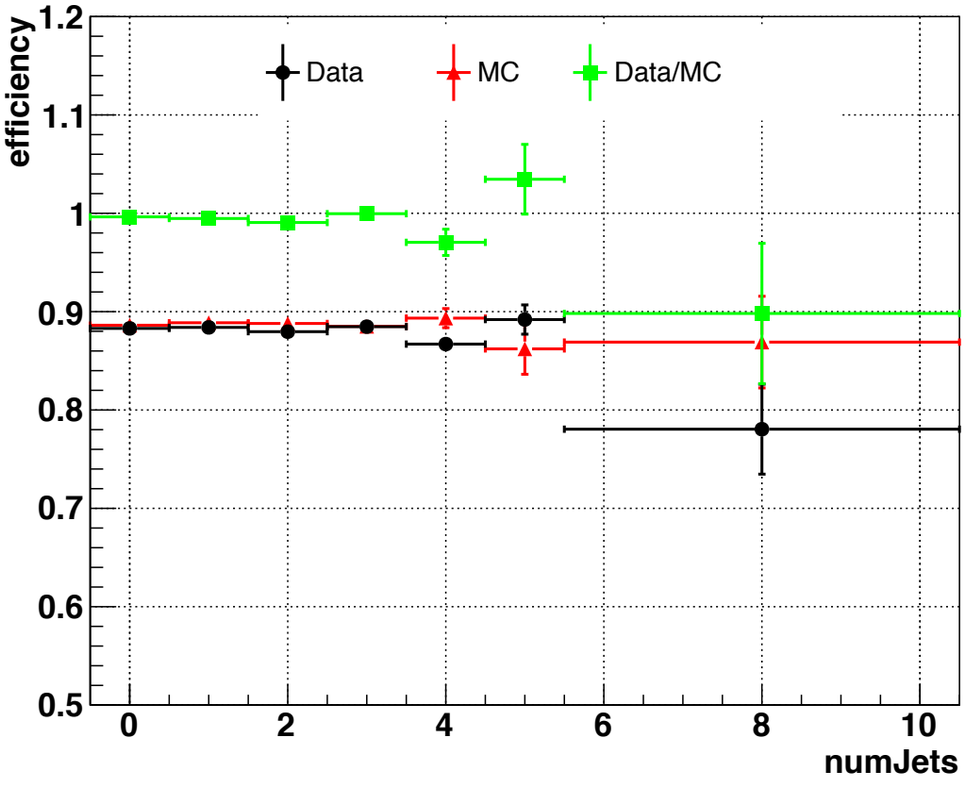
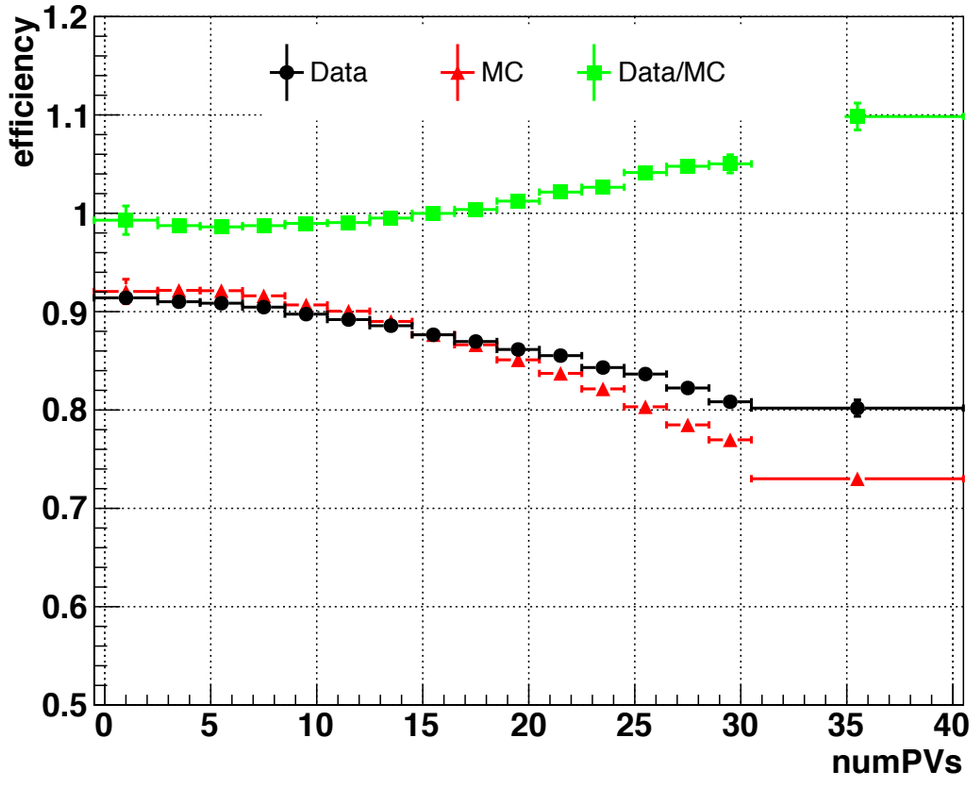
Muon: HLT









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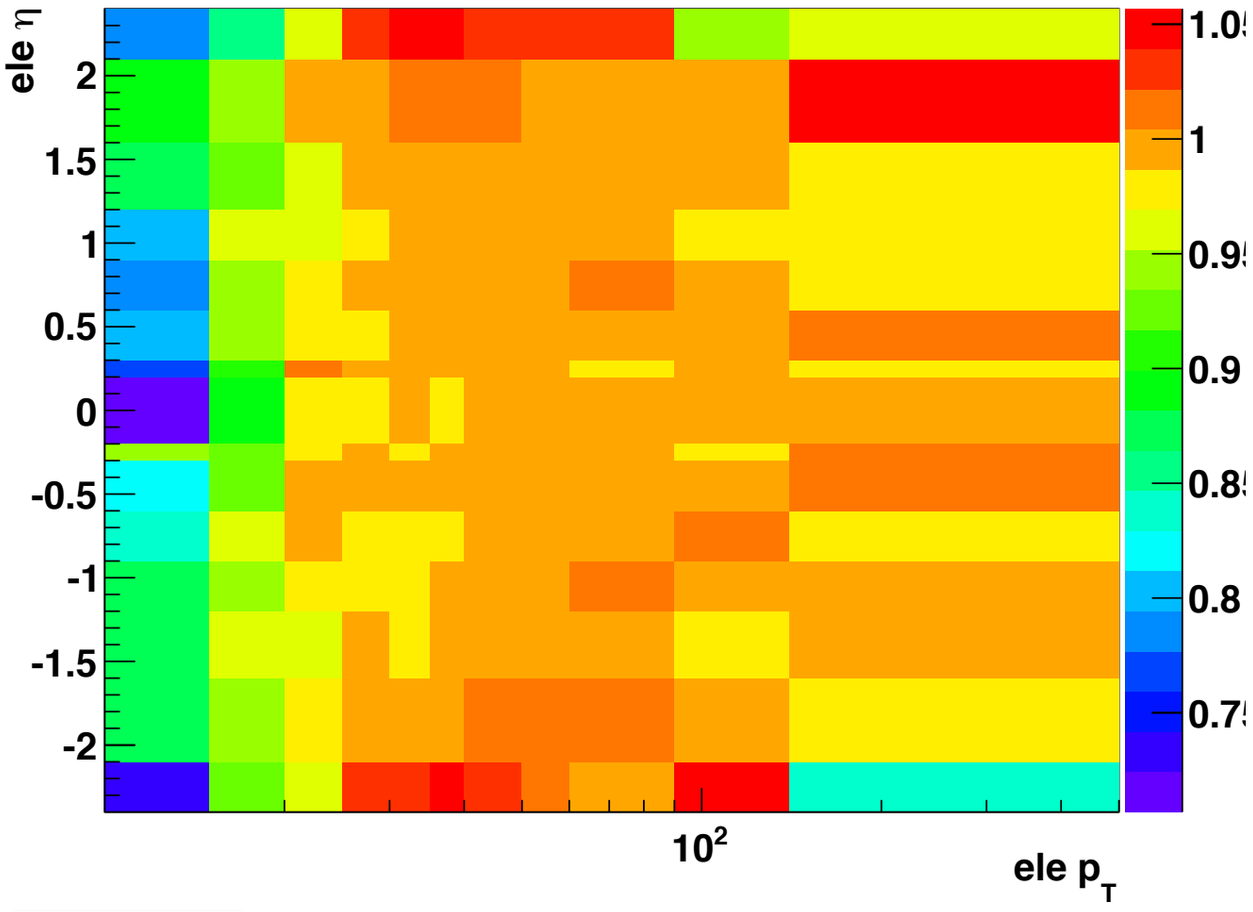
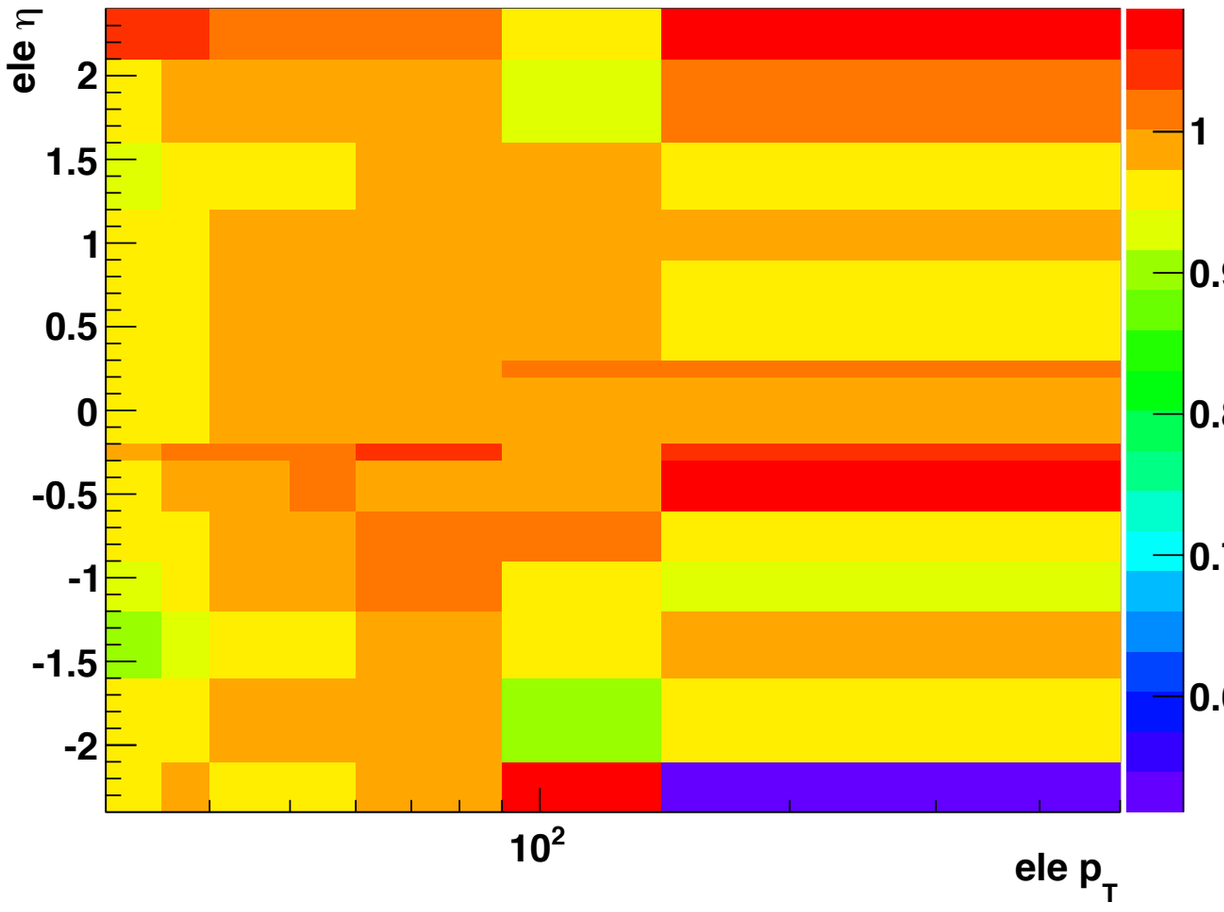
Electron scale factors: figures

- In general, good agreement between data and MC

id + isolation



id + isolation + HLT



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Electron scale factors: numbers

id + isolation

eta / pT	(30, 35)	(35, 40)	(40, 50)	(50, 60)	(60, 90)	(90, 140)	(140, 500)
(-2.4, -2.1)	1.031 ± 0.012	1.043 ± 0.009	1.030 ± 0.006	1.019 ± 0.012	0.995 ± 0.022	1.043 ± 0.059	0.831 ± 0.105
(-2.1, -1.6)	1.002 ± 0.006	0.997 ± 0.005	1.010 ± 0.003	1.008 ± 0.006	1.012 ± 0.011	0.992 ± 0.028	0.971 ± 0.057
(-1.6, -1.2)	0.984 ± 0.005	0.991 ± 0.004	0.995 ± 0.002	1.001 ± 0.005	0.999 ± 0.007	0.986 ± 0.019	0.995 ± 0.041
(-1.2, -0.9)	0.982 ± 0.004	0.987 ± 0.003	0.992 ± 0.002	0.999 ± 0.004	1.005 ± 0.006	0.990 ± 0.012	0.993 ± 0.021
(-0.9, -0.6)	0.977 ± 0.004	0.985 ± 0.003	0.995 ± 0.002	0.987 ± 0.003	0.997 ± 0.005	1.008 ± 0.015	0.985 ± 0.026
(-0.6, -0.3)	0.989 ± 0.003	0.994 ± 0.003	0.991 ± 0.001	0.994 ± 0.003	0.987 ± 0.004	0.990 ± 0.011	1.021 ± 0.021
(-0.3, -0.2)	0.985 ± 0.006	0.994 ± 0.005	0.991 ± 0.002	0.995 ± 0.005	0.999 ± 0.009	0.979 ± 0.020	1.016 ± 0.009
(-0.2, 0.2)	0.989 ± 0.003	0.986 ± 0.002	0.991 ± 0.001	0.994 ± 0.002	0.990 ± 0.004	0.994 ± 0.009	0.991 ± 0.010
(0.2, 0.3)	0.996 ± 0.006	0.995 ± 0.004	0.992 ± 0.002	0.992 ± 0.005	0.983 ± 0.007	0.988 ± 0.013	0.975 ± 0.018
(0.3, 0.6)	0.990 ± 0.003	0.991 ± 0.002	0.995 ± 0.001	0.998 ± 0.003	0.997 ± 0.005	0.992 ± 0.013	1.015 ± 0.015
(0.6, 0.9)	0.989 ± 0.004	0.994 ± 0.003	0.995 ± 0.002	0.996 ± 0.003	1.006 ± 0.006	0.995 ± 0.013	0.977 ± 0.019
(0.9, 1.2)	0.988 ± 0.004	0.991 ± 0.003	0.997 ± 0.002	0.997 ± 0.003	1.002 ± 0.006	0.983 ± 0.014	0.985 ± 0.021
(1.2, 1.6)	0.995 ± 0.006	0.991 ± 0.004	0.990 ± 0.002	0.991 ± 0.005	0.991 ± 0.007	0.990 ± 0.024	0.986 ± 0.032
(1.6, 2.1)	1.015 ± 0.006	1.009 ± 0.005	1.012 ± 0.003	1.004 ± 0.006	1.000 ± 0.010	0.996 ± 0.026	1.056 ± 0.065
(2.1, 2.4)	1.057 ± 0.013	1.040 ± 0.009	1.028 ± 0.006	1.027 ± 0.012	1.037 ± 0.021	0.938 ± 0.059	0.957 ± 0.114

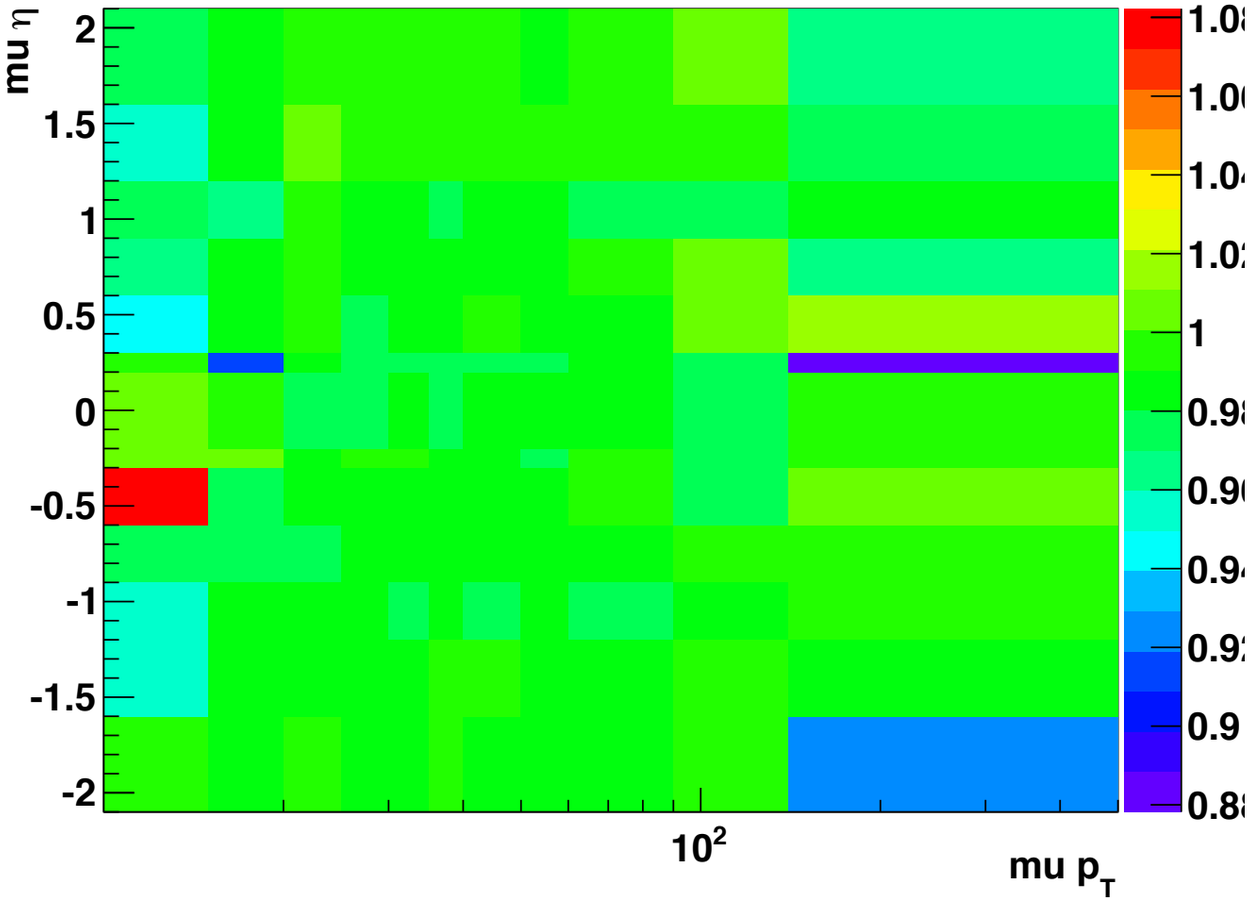
id + isolation + HLT

eta / pT	(30, 35)	(35, 40)	(40, 50)	(50, 60)	(60, 90)	(90, 140)	(140, 500)
(-2.4, -2.1)	0.945 ± 0.020	0.975 ± 0.016	0.945 ± 0.010	0.947 ± 0.022	0.973 ± 0.039	1.087 ± 0.106	0.518 ± 0.114
(-2.1, -1.6)	0.946 ± 0.012	0.961 ± 0.009	0.976 ± 0.005	0.976 ± 0.010	0.985 ± 0.018	0.907 ± 0.044	0.948 ± 0.101
(-1.6, -1.2)	0.906 ± 0.008	0.942 ± 0.006	0.970 ± 0.004	0.969 ± 0.007	0.985 ± 0.011	0.972 ± 0.025	0.991 ± 0.047
(-1.2, -0.9)	0.934 ± 0.006	0.962 ± 0.005	0.978 ± 0.003	0.978 ± 0.006	1.002 ± 0.009	0.957 ± 0.017	0.944 ± 0.028
(-0.9, -0.6)	0.956 ± 0.006	0.970 ± 0.004	0.991 ± 0.003	0.990 ± 0.005	1.002 ± 0.009	1.021 ± 0.025	0.971 ± 0.037
(-0.6, -0.3)	0.973 ± 0.006	0.998 ± 0.005	0.999 ± 0.003	1.004 ± 0.006	0.980 ± 0.008	1.001 ± 0.022	1.086 ± 0.057
(-0.3, -0.2)	1.000 ± 0.012	1.002 ± 0.008	1.009 ± 0.005	1.003 ± 0.010	1.034 ± 0.018	0.976 ± 0.033	1.043 ± 0.034
(-0.2, 0.2)	0.965 ± 0.006	0.972 ± 0.004	0.984 ± 0.002	0.992 ± 0.005	0.987 ± 0.007	0.991 ± 0.015	0.980 ± 0.025
(0.2, 0.3)	0.970 ± 0.011	0.973 ± 0.008	0.992 ± 0.005	0.985 ± 0.010	0.979 ± 0.014	1.014 ± 0.032	1.004 ± 0.040
(0.3, 0.6)	0.959 ± 0.006	0.971 ± 0.004	0.984 ± 0.003	0.983 ± 0.005	0.980 ± 0.008	0.973 ± 0.020	0.966 ± 0.025
(0.6, 0.9)	0.958 ± 0.006	0.972 ± 0.004	0.988 ± 0.003	0.981 ± 0.005	0.997 ± 0.008	0.977 ± 0.020	0.963 ± 0.036
(0.9, 1.2)	0.951 ± 0.007	0.964 ± 0.004	0.979 ± 0.003	0.983 ± 0.005	0.985 ± 0.009	0.999 ± 0.024	0.988 ± 0.033
(1.2, 1.6)	0.924 ± 0.009	0.962 ± 0.006	0.973 ± 0.004	0.968 ± 0.007	0.979 ± 0.011	0.993 ± 0.029	0.965 ± 0.040
(1.6, 2.1)	0.967 ± 0.011	0.994 ± 0.009	0.991 ± 0.005	0.979 ± 0.010	0.974 ± 0.017	0.916 ± 0.039	1.008 ± 0.095
(2.1, 2.4)	1.034 ± 0.023	1.044 ± 0.018	1.002 ± 0.011	1.012 ± 0.023	1.012 ± 0.039	0.972 ± 0.115	1.067 ± 0.310

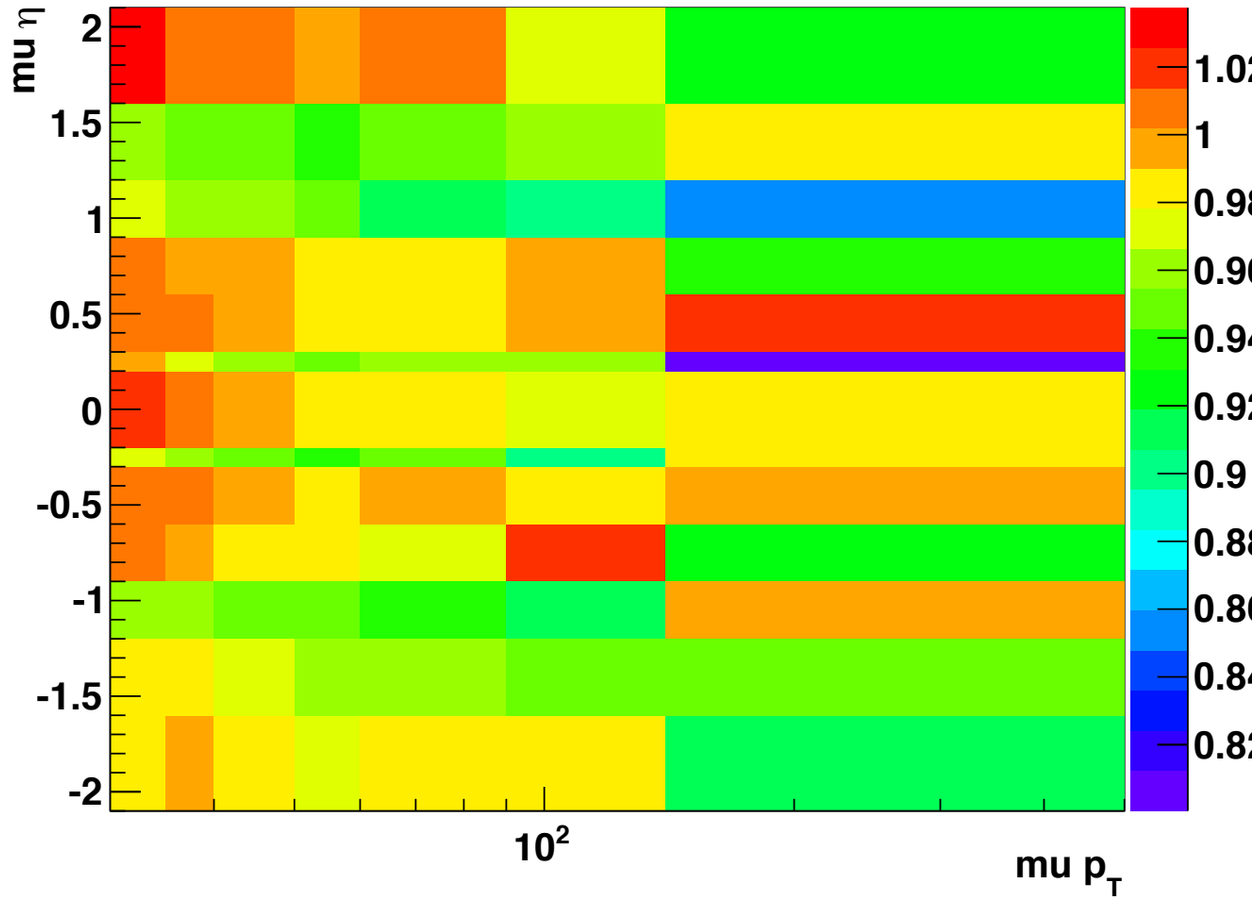
Muon scale factors: figures

- In general, good agreement between data and MC

id + isolation



id + isolation + HLT



Muon scale factors: numbers

id + isolation

eta / pT	(30, 35)	(35, 40)	(40, 50)	(50, 60)	(60, 90)	(90, 140)	(140, 500)
(-2.1, -1.6)	0.986 ± 0.003	0.990 ± 0.003	0.988 ± 0.001	0.987 ± 0.003	0.989 ± 0.006	0.998 ± 0.018	0.929 ± 0.029
(-1.6, -1.2)	0.987 ± 0.003	0.995 ± 0.002	0.993 ± 0.001	0.987 ± 0.002	0.989 ± 0.004	0.998 ± 0.011	0.988 ± 0.019
(-1.2, -0.9)	0.973 ± 0.003	0.981 ± 0.003	0.979 ± 0.001	0.982 ± 0.003	0.973 ± 0.005	0.987 ± 0.013	0.990 ± 0.024
(-0.9, -0.6)	0.987 ± 0.003	0.985 ± 0.002	0.988 ± 0.001	0.985 ± 0.003	0.987 ± 0.005	0.996 ± 0.015	0.991 ± 0.014
(-0.6, -0.3)	0.987 ± 0.003	0.986 ± 0.002	0.989 ± 0.001	0.986 ± 0.002	0.995 ± 0.004	0.976 ± 0.009	1.004 ± 0.020
(-0.3, -0.2)	0.995 ± 0.007	0.985 ± 0.005	0.984 ± 0.003	0.978 ± 0.007	0.992 ± 0.010	0.971 ± 0.025	0.992 ± 0.045
(-0.2, 0.2)	0.982 ± 0.003	0.980 ± 0.002	0.983 ± 0.001	0.981 ± 0.003	0.984 ± 0.004	0.973 ± 0.009	1.000 ± 0.017
(0.2, 0.3)	0.979 ± 0.006	0.973 ± 0.005	0.980 ± 0.003	0.975 ± 0.006	0.983 ± 0.011	0.978 ± 0.027	0.878 ± 0.043
(0.3, 0.6)	0.987 ± 0.003	0.989 ± 0.002	0.990 ± 0.001	0.990 ± 0.002	0.988 ± 0.004	1.003 ± 0.009	1.015 ± 0.024
(0.6, 0.9)	0.981 ± 0.003	0.989 ± 0.002	0.987 ± 0.001	0.990 ± 0.003	0.995 ± 0.005	1.002 ± 0.013	0.968 ± 0.019
(0.9, 1.2)	0.988 ± 0.004	0.978 ± 0.003	0.987 ± 0.001	0.982 ± 0.003	0.978 ± 0.005	0.977 ± 0.011	0.984 ± 0.027
(1.2, 1.6)	0.992 ± 0.003	0.993 ± 0.002	0.992 ± 0.001	0.993 ± 0.002	0.991 ± 0.004	0.990 ± 0.014	0.976 ± 0.016
(1.6, 2.1)	1.000 ± 0.003	0.995 ± 0.002	0.995 ± 0.001	0.990 ± 0.003	0.992 ± 0.004	1.002 ± 0.015	0.960 ± 0.031

id + isolation + HLT

eta / pT	(30, 35)	(35, 40)	(40, 50)	(50, 60)	(60, 90)	(90, 140)	(140, 500)
(-2.1, -1.6)	0.983 ± 0.007	0.991 ± 0.006	0.978 ± 0.004	0.972 ± 0.007	0.978 ± 0.014	0.982 ± 0.038	0.910 ± 0.064
(-1.6, -1.2)	0.981 ± 0.006	0.982 ± 0.005	0.975 ± 0.003	0.964 ± 0.006	0.955 ± 0.009	0.954 ± 0.025	0.950 ± 0.042
(-1.2, -0.9)	0.964 ± 0.006	0.959 ± 0.005	0.946 ± 0.003	0.945 ± 0.006	0.941 ± 0.010	0.918 ± 0.024	0.993 ± 0.065
(-0.9, -0.6)	1.011 ± 0.005	0.993 ± 0.003	0.989 ± 0.002	0.979 ± 0.004	0.978 ± 0.007	1.019 ± 0.022	0.926 ± 0.023
(-0.6, -0.3)	1.011 ± 0.004	1.012 ± 0.003	0.998 ± 0.002	0.989 ± 0.004	0.991 ± 0.006	0.979 ± 0.017	0.995 ± 0.024
(-0.3, -0.2)	0.968 ± 0.009	0.962 ± 0.007	0.951 ± 0.004	0.938 ± 0.009	0.952 ± 0.015	0.897 ± 0.034	0.986 ± 0.074
(-0.2, 0.2)	1.015 ± 0.004	1.002 ± 0.003	0.993 ± 0.002	0.979 ± 0.004	0.986 ± 0.006	0.976 ± 0.020	0.986 ± 0.025
(0.2, 0.3)	0.994 ± 0.009	0.974 ± 0.007	0.964 ± 0.004	0.952 ± 0.009	0.963 ± 0.016	0.961 ± 0.039	0.800 ± 0.051
(0.3, 0.6)	1.013 ± 0.004	1.008 ± 0.003	0.999 ± 0.002	0.987 ± 0.004	0.986 ± 0.006	0.997 ± 0.015	1.021 ± 0.037
(0.6, 0.9)	1.010 ± 0.005	1.001 ± 0.003	0.990 ± 0.002	0.984 ± 0.004	0.986 ± 0.007	1.001 ± 0.020	0.937 ± 0.041
(0.9, 1.2)	0.971 ± 0.007	0.964 ± 0.005	0.959 ± 0.003	0.948 ± 0.006	0.916 ± 0.009	0.900 ± 0.021	0.855 ± 0.043
(1.2, 1.6)	0.963 ± 0.006	0.954 ± 0.005	0.945 ± 0.003	0.939 ± 0.006	0.949 ± 0.010	0.956 ± 0.031	0.980 ± 0.060
(1.6, 2.1)	1.037 ± 0.007	1.013 ± 0.005	1.010 ± 0.003	0.990 ± 0.007	1.006 ± 0.012	0.971 ± 0.031	0.930 ± 0.070

Low p_T id + iso scale factors: DIL

electrons

eta / pT	(10, 15)	(15, 20)	(20, 25)	(25, 30)
(-2.4, -2.1)	0.735 ± 0.052	0.933 ± 0.038	0.959 ± 0.021	1.037 ± 0.017
(-2.1, -1.6)	0.872 ± 0.029	0.942 ± 0.018	0.976 ± 0.012	1.001 ± 0.009
(-1.6, -1.2)	0.866 ± 0.039	0.956 ± 0.022	0.957 ± 0.011	0.994 ± 0.008
(-1.2, -0.9)	0.878 ± 0.040	0.936 ± 0.021	0.976 ± 0.010	0.979 ± 0.006
(-0.9, -0.6)	0.843 ± 0.047	0.963 ± 0.025	0.988 ± 0.011	0.983 ± 0.006
(-0.6, -0.3)	0.822 ± 0.054	0.928 ± 0.022	1.001 ± 0.010	0.996 ± 0.006
(-0.3, -0.2)	0.945 ± 0.142	0.925 ± 0.042	0.975 ± 0.016	0.990 ± 0.010
(-0.2, 0.2)	0.707 ± 0.055	0.892 ± 0.020	0.975 ± 0.008	0.980 ± 0.005
(0.2, 0.3)	0.761 ± 0.101	0.914 ± 0.036	1.007 ± 0.017	0.998 ± 0.010
(0.3, 0.6)	0.794 ± 0.050	0.949 ± 0.022	0.986 ± 0.009	0.986 ± 0.005
(0.6, 0.9)	0.786 ± 0.042	0.949 ± 0.023	0.977 ± 0.010	0.992 ± 0.006
(0.9, 1.2)	0.811 ± 0.039	0.958 ± 0.024	0.968 ± 0.010	0.979 ± 0.006
(1.2, 1.6)	0.871 ± 0.039	0.927 ± 0.020	0.966 ± 0.011	0.987 ± 0.008
(1.6, 2.1)	0.891 ± 0.030	0.951 ± 0.018	0.998 ± 0.013	0.995 ± 0.008
(2.1, 2.4)	0.784 ± 0.049	0.857 ± 0.031	0.957 ± 0.022	1.022 ± 0.016

muons

eta / pT	(10, 15)	(15, 20)	(20, 25)	(25, 30)
(-2.1, -1.6)	0.992 ± 0.016	0.980 ± 0.010	0.992 ± 0.007	0.990 ± 0.005
(-1.6, -1.2)	0.956 ± 0.013	0.981 ± 0.010	0.983 ± 0.006	0.990 ± 0.004
(-1.2, -0.9)	0.957 ± 0.021	0.983 ± 0.013	0.982 ± 0.008	0.983 ± 0.006
(-0.9, -0.6)	0.977 ± 0.023	0.971 ± 0.012	0.978 ± 0.008	0.986 ± 0.005
(-0.6, -0.3)	1.082 ± 0.040	0.972 ± 0.012	0.981 ± 0.008	0.982 ± 0.005
(-0.3, -0.2)	1.004 ± 0.043	1.009 ± 0.032	0.982 ± 0.016	0.993 ± 0.010
(-0.2, 0.2)	1.008 ± 0.030	0.992 ± 0.013	0.972 ± 0.007	0.974 ± 0.004
(0.2, 0.3)	0.991 ± 0.070	0.915 ± 0.020	0.988 ± 0.018	0.975 ± 0.010
(0.3, 0.6)	0.945 ± 0.021	0.987 ± 0.014	0.999 ± 0.009	0.980 ± 0.005
(0.6, 0.9)	0.965 ± 0.019	0.989 ± 0.014	0.994 ± 0.008	0.982 ± 0.005
(0.9, 1.2)	0.970 ± 0.018	0.960 ± 0.011	0.994 ± 0.009	0.990 ± 0.006
(1.2, 1.6)	0.952 ± 0.014	0.980 ± 0.011	1.005 ± 0.008	0.990 ± 0.005
(1.6, 2.1)	0.972 ± 0.013	0.988 ± 0.010	0.999 ± 0.007	0.992 ± 0.004

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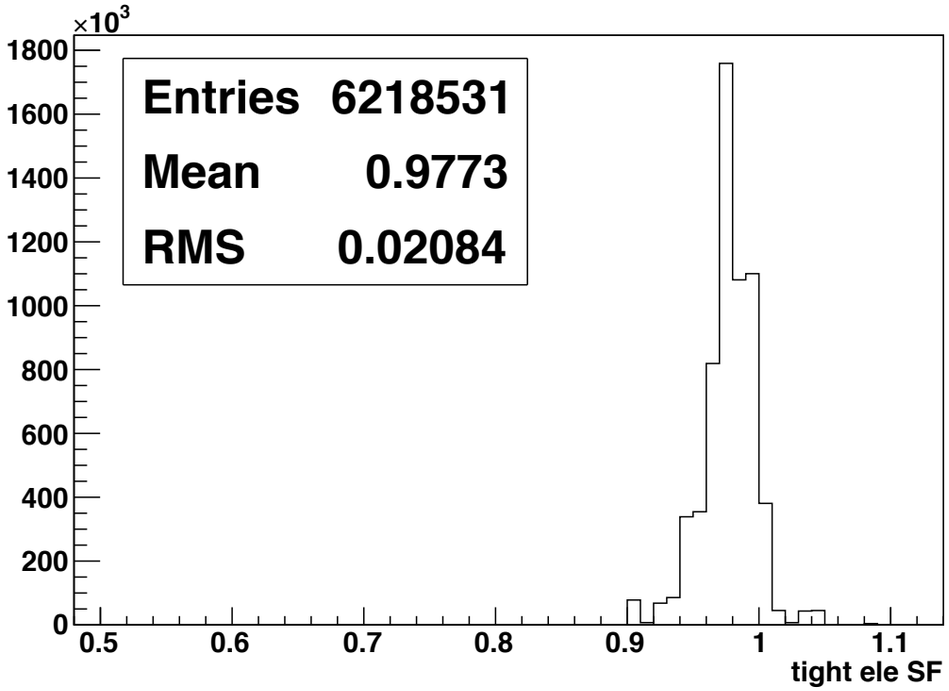
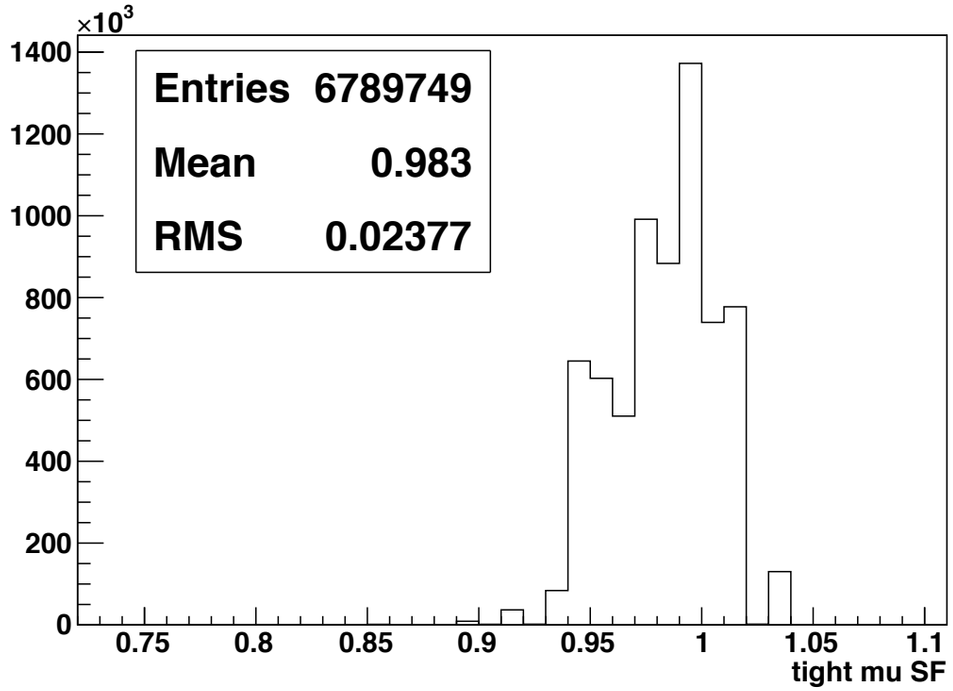
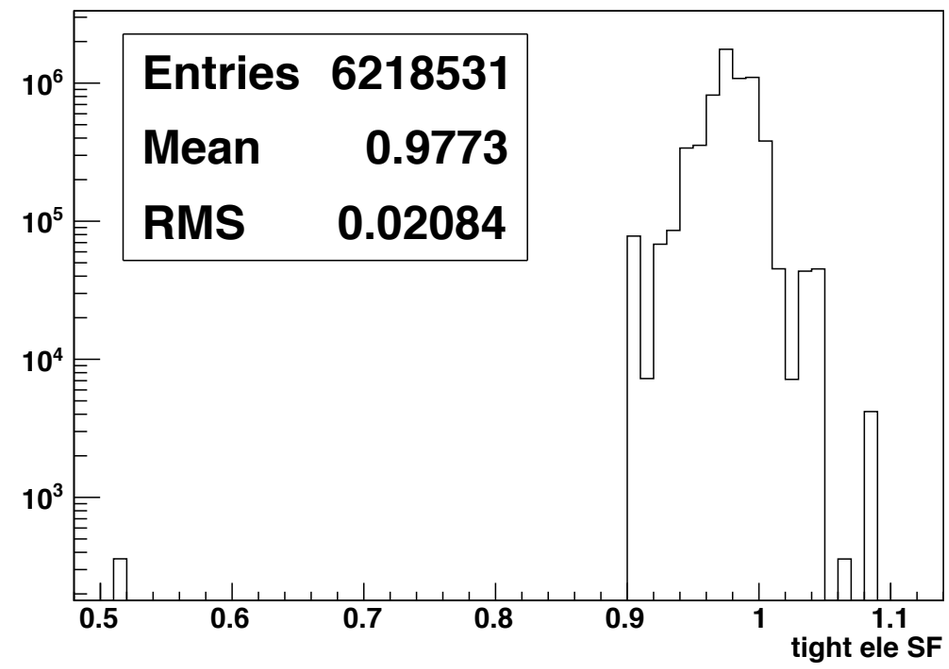
Scale factors (DYJetsToLL)

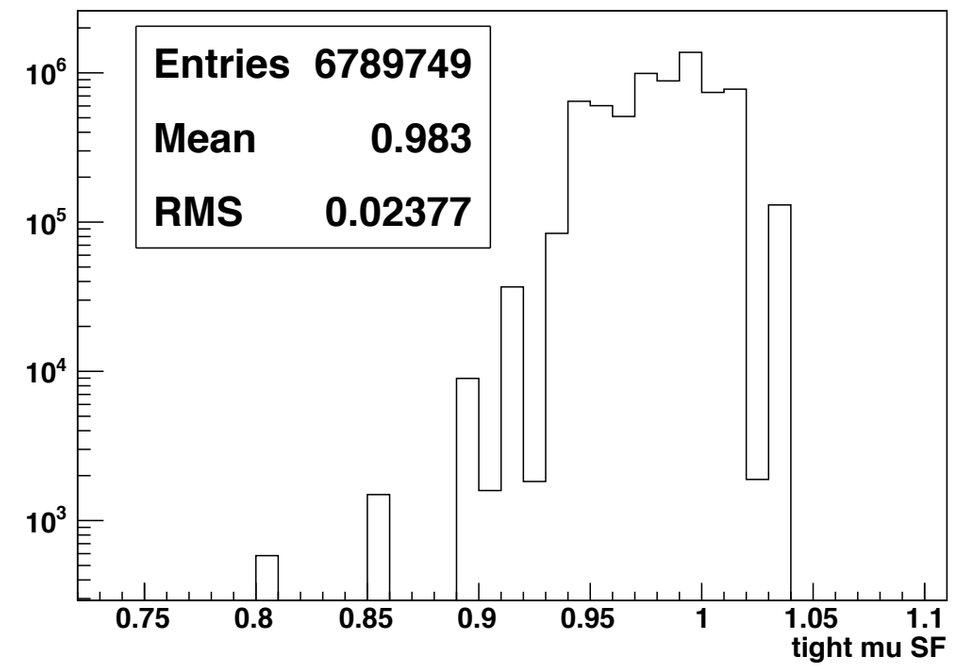




electrons



muons



Summary

- Derived lepton scale factors for electrons and muons
- Implemented in BEANsUtilities.h
  - Different behavior for isLJ = true/false
    - DIL includes id + iso SF
    - LJ includes id + iso + HLT SF
  - Works for loose and tight leptons
- No uncertainties
  - Use flat error: SF +/- 0.04 (open for debate)
- Can be improved in the future
  - Better binning
  - Run2012C + additional data
  - Feedback is very welcome