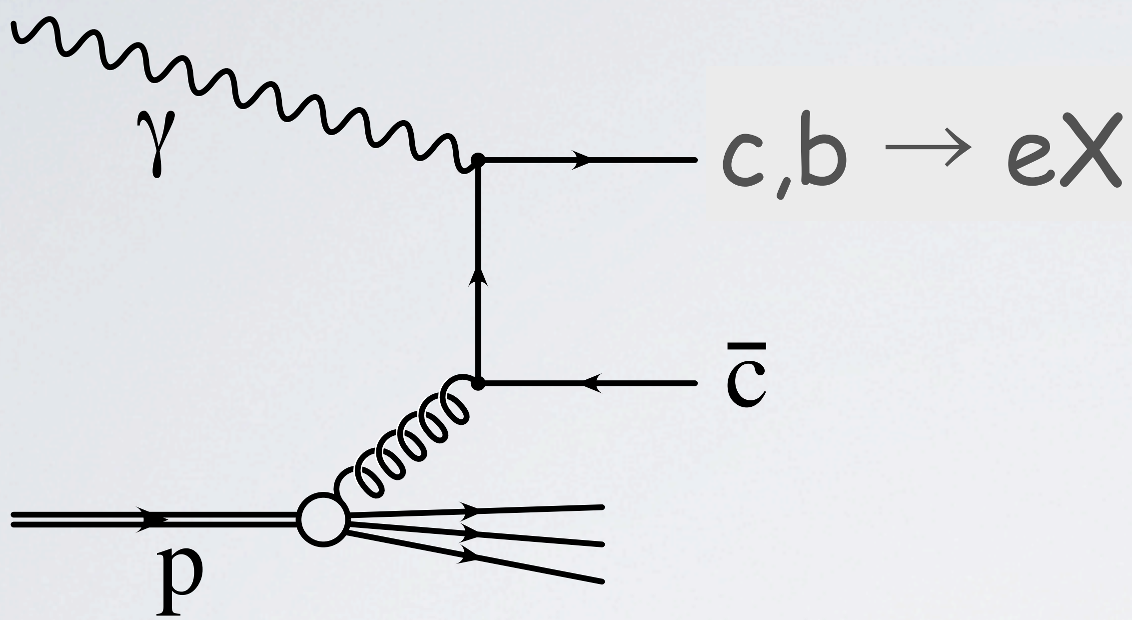
CHARM & BEAUTY WITH ELECTRONS

Martin Brinkmann, Karin Daum

MOTIVATION - AIM OF THIS ANALYSIS

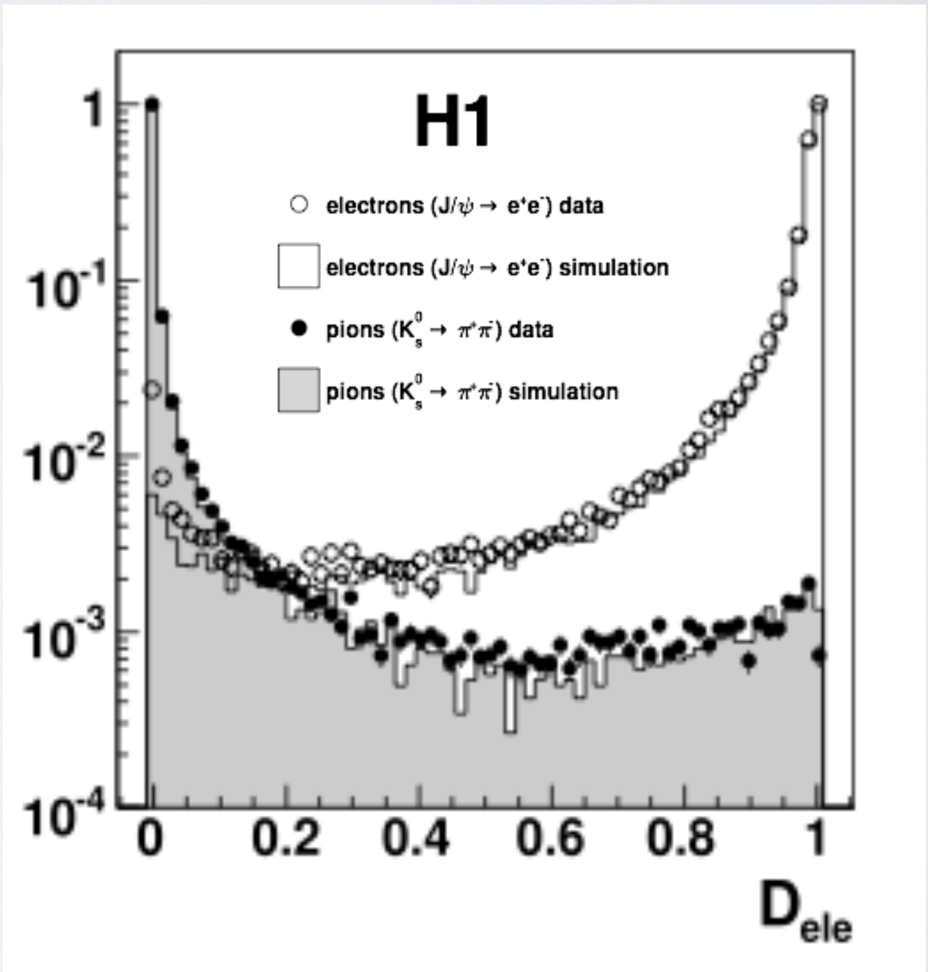


- ☞ We have an excellent e/π discriminator

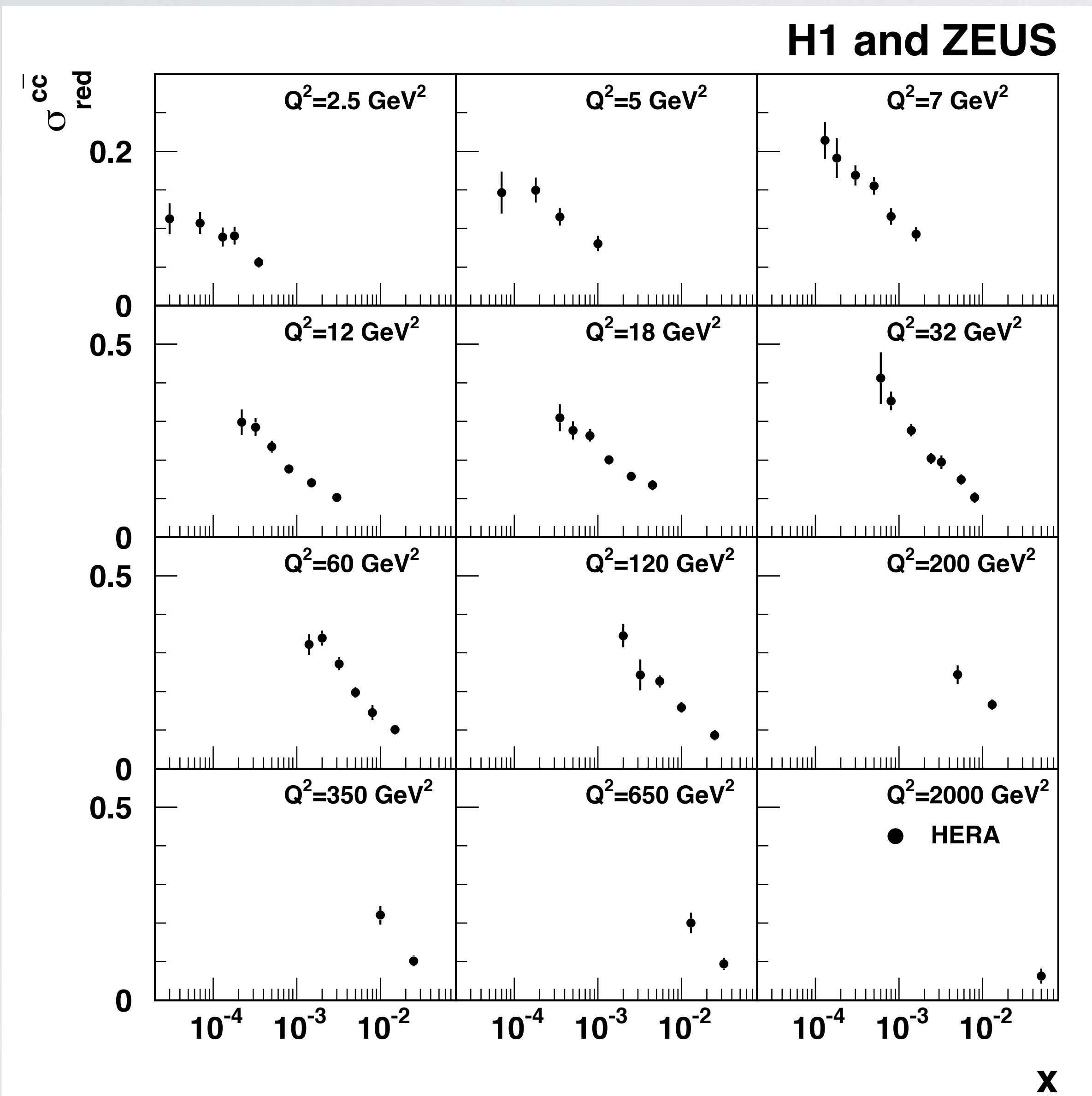
  π-suppression by a factor 300!
- ☞ large leptonic branching fractions for c/b

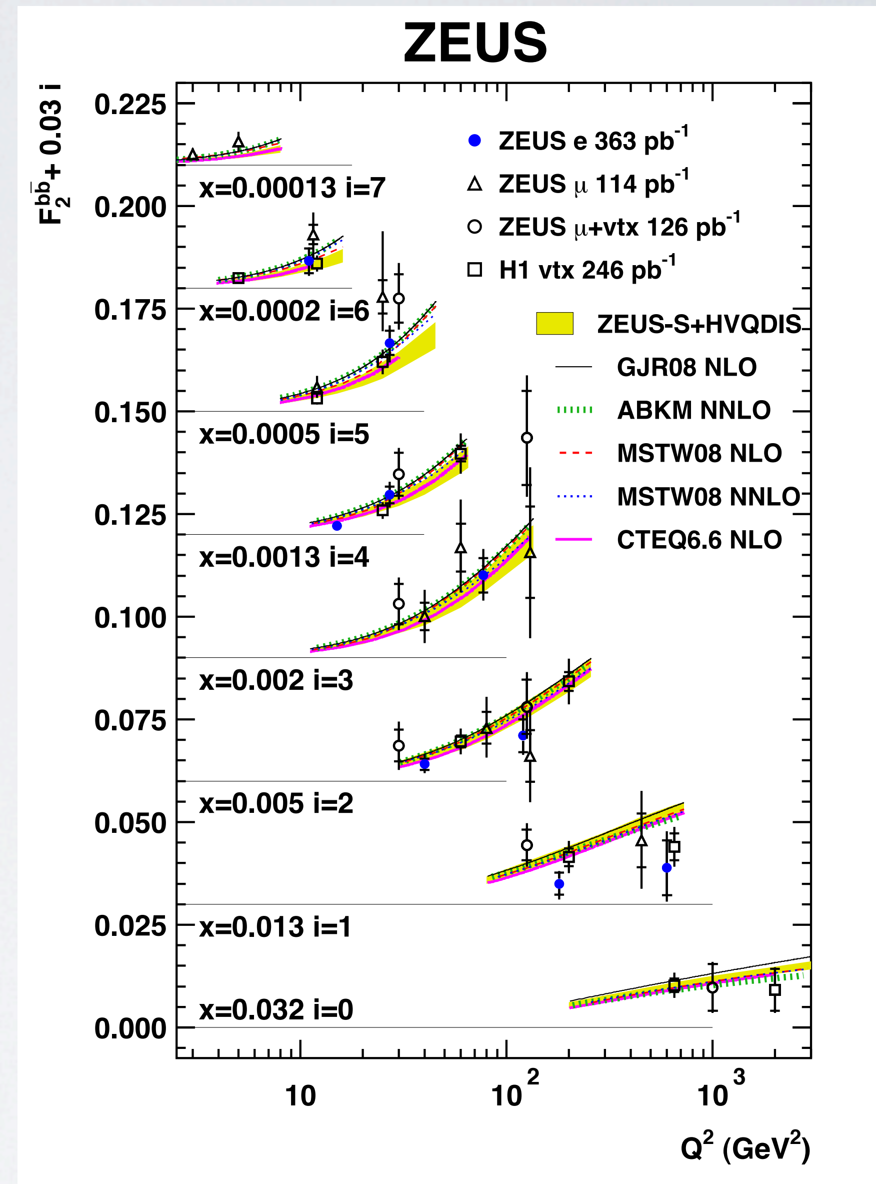
  high statistics
- ☞ analysis orthogonal to other

  measurements to profit from combination



MOTIVATION - F_2^{CC} AND F_2^{BB}

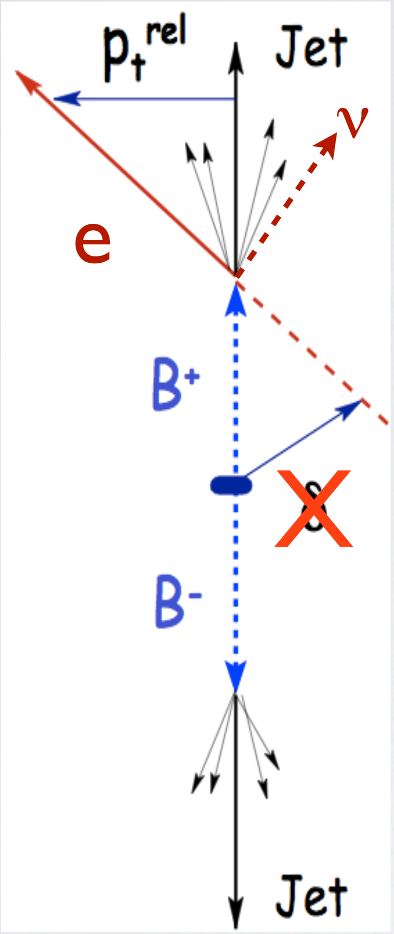




currently 5-6% error @ medium Q^2
goal: 3-4% with c→e and new ZEUS D*

currently 20-30% error
10% from b→e feasible

METHOD



Analysis is based on semi-electronic decays of heavy flavoured hadrons

Orthogonality w.r.t. other analyses constrains the choice of observables

⇒ p_T^{rel} of electron

⇒ missing momentum from neutrino

⇒ jet mass, multiplicity.....

needs good modelling of DIS, HFS, Jets

Everything marked in red in this talk are modifications w.r.t. Martin's analysis

DATA SAMPLES AND SELECTION

2005-2007 $\mathcal{L}$=301 pb^{-1}

Triggers: ST6, ST67

DIS phase space:

$5<Q^2<2000$ GeV^2 , $0.02<y_{e\Sigma}<0.7$

Electron selection:

SpaCal: same as D* @ low Q^2
LAr: same as D* @ high Q^2

HFS:

iterative calibration
correction of hadronic energy in SpaCal (1.25 for data, 1.5 for MC) as used for F_L^D

35GeV < $E-P_Z$ < 70 GeV

Jets:
k_T algorithm, γp frame, R=1.5
(from Susanne Hellwig's diploma thesis)
$P_T^*>1.5$ GeV

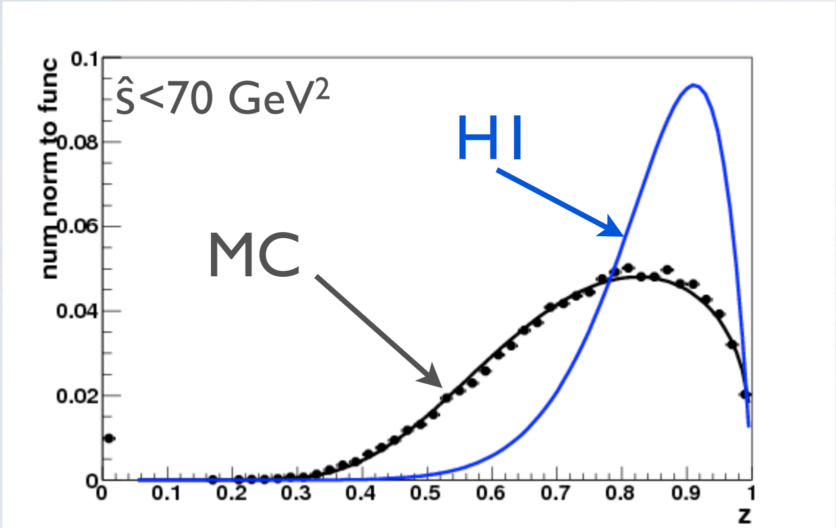
Soft electron candidates:
$0.7<P_T<25$ GeV, $|\eta|<1.3$
Vetos: $\pi\rightarrow ee\gamma$, $\gamma\rightarrow ee$, QEDC
contained in the leading or next-to-leading jet (γp)
Electron discriminator output:
signal region: >0.9
background region: 0.75-0.9
(variable lower limit for systematics)

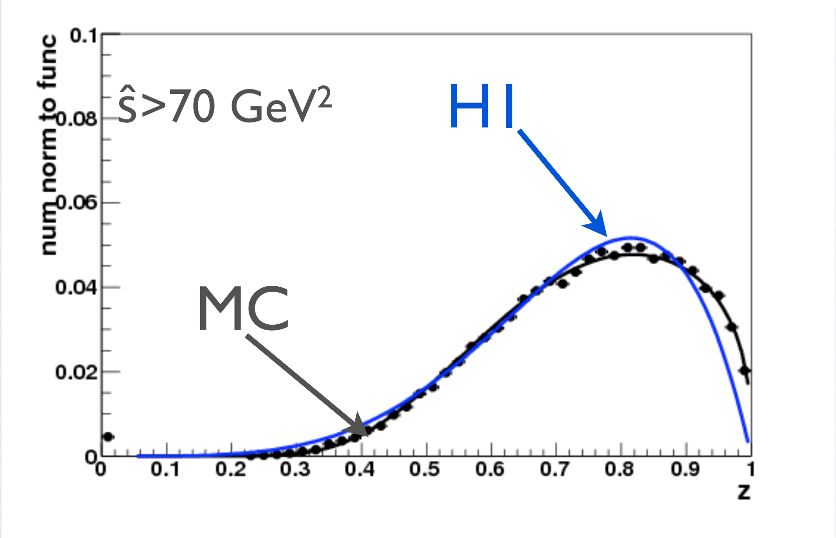
MONTE CARLO SAMPLES

light flavours	RAPGAP 8773-8784, 8849-8860	400,000,000 events $\mathcal{L}$=1,459 pb^{-1}
charm	RAPGAP 8785-8790	120,000,000 events $\mathcal{L}$=2,853 pb^{-1}
beauty	RAPGAP 8750-8753	20,000,000 events $\mathcal{L}$=27,504 pb^{-1}
Diffraction uds	RAPGAP 7222	6,000,000 events $\mathcal{L}$=261 pb^{-1}
Diffraction charm	RAPGAP 7223	1,200,000 events $\mathcal{L}$=286 pb^{-1}
Inelastic J/ψ	CASCADE 8836	1,000,000 events $\mathcal{L}$=32,407 pb^{-1}

HEAVY FLAVOUR RE-WEIGHTING IN MC

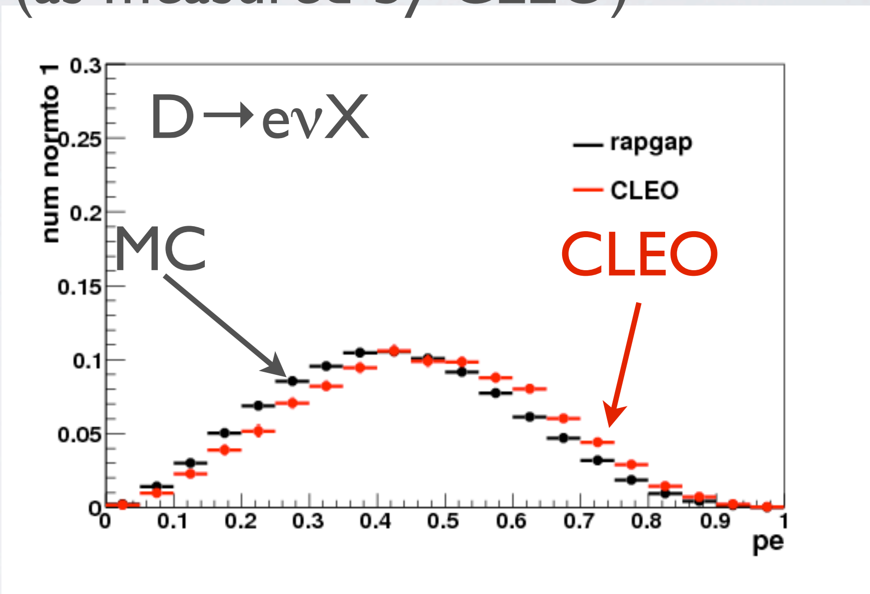
Charm fragmentation
(as measured by H1)





Re-weighting applied for D→eνX (gen, rec)
and to all hadrons misidentified as electrons from decay or string (rec)

Electron decay spectrum
(as measured by CLEO)



M.Brimkman
PAF 22.01.13
20.02.13

Re-weighting applied for D→eνX (gen, rec)
(how to treat misidentified hadrons from decays unclear)

Reasonable agreement (data vs. MC)observed for B→eνX (Belle) and fragmentation ⇒ no

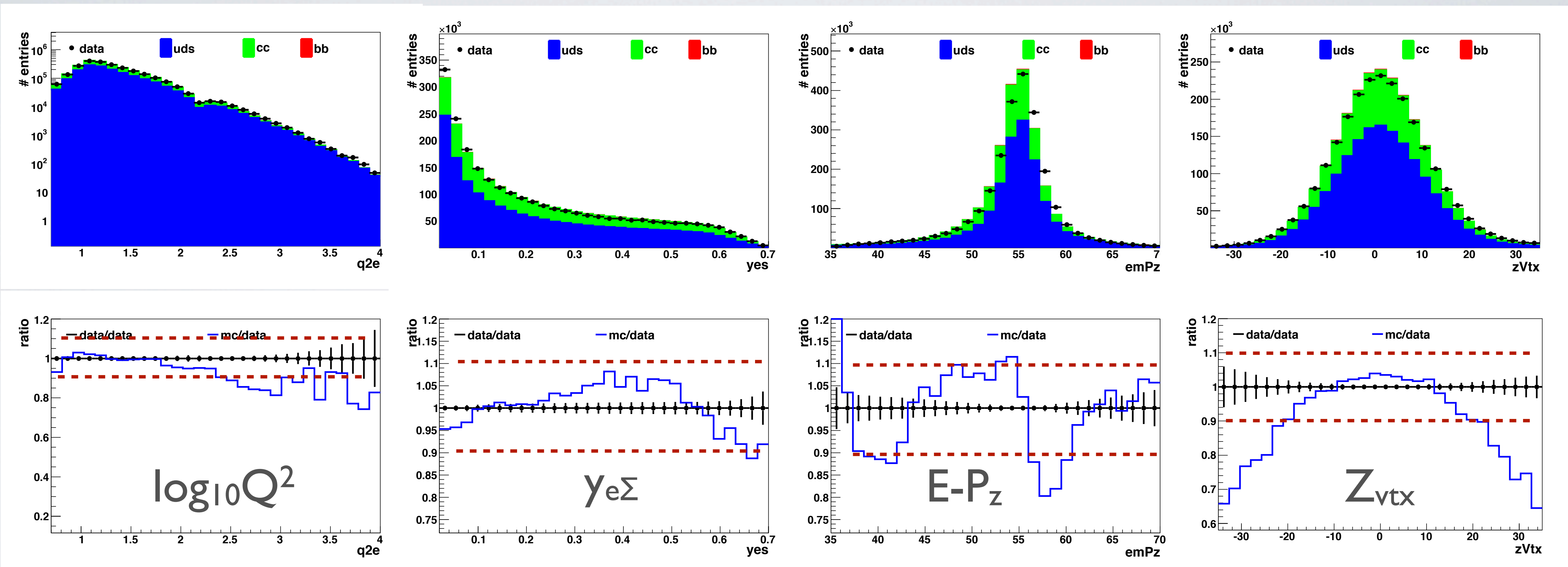
re-weights applied (check again!)

ANALYSIS STEPS - CHECKLIST

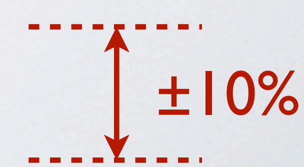
Lumi	
Inclusive DIS	✔
Inclusive Jets	✔
Inclusive HFS	(✔)
Soft electron discriminator	
electron efficiency	✔
pion suppression (K^0_s)	✔
proton suppression (Λ)	✔
Fraction fits	✔
Efficiencies	
Trigger efficiency	
Reconstruction effciency	(✔)
Radiative Corrections	
Systematic uncertainties	
NLO Predictions	✔

✔ = checked/added - red = changes or new - thin = not done yet

INCLUSIVE SAMPLE

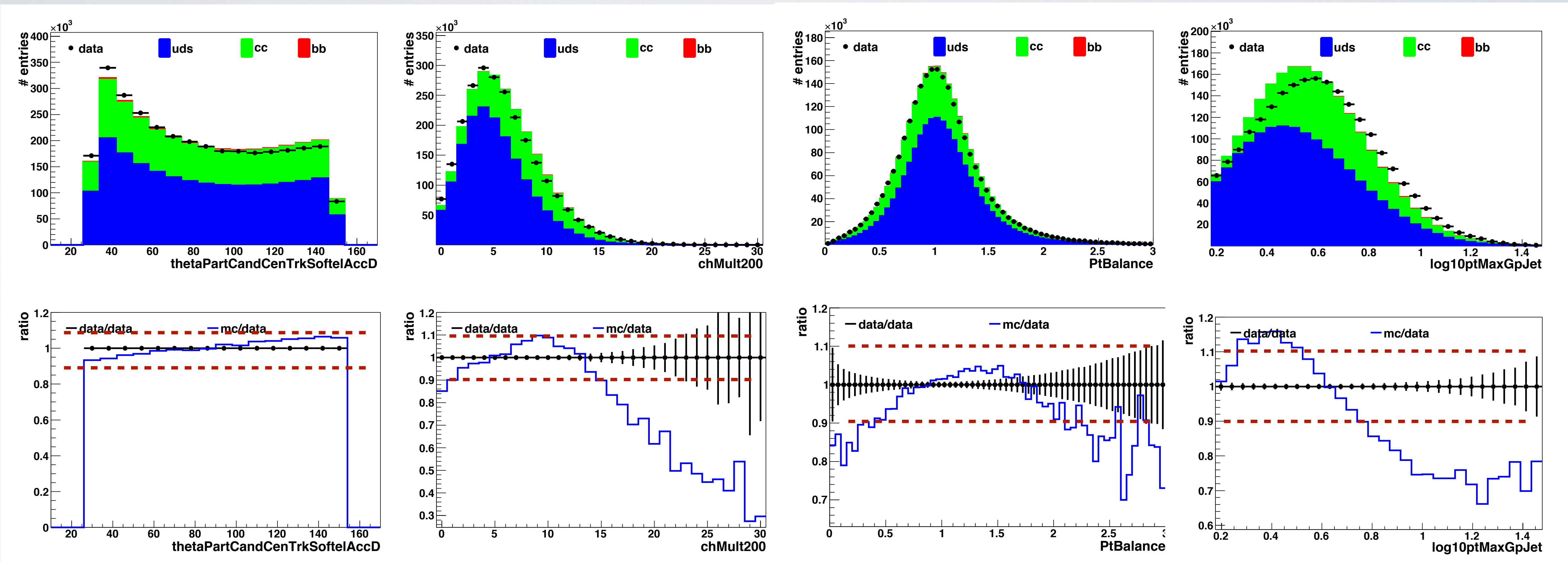


☞ MC needs to be re-weighted in Z_{vtx} and y (to start with)

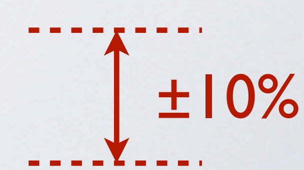


INCLUSIVE HFS AND JETS

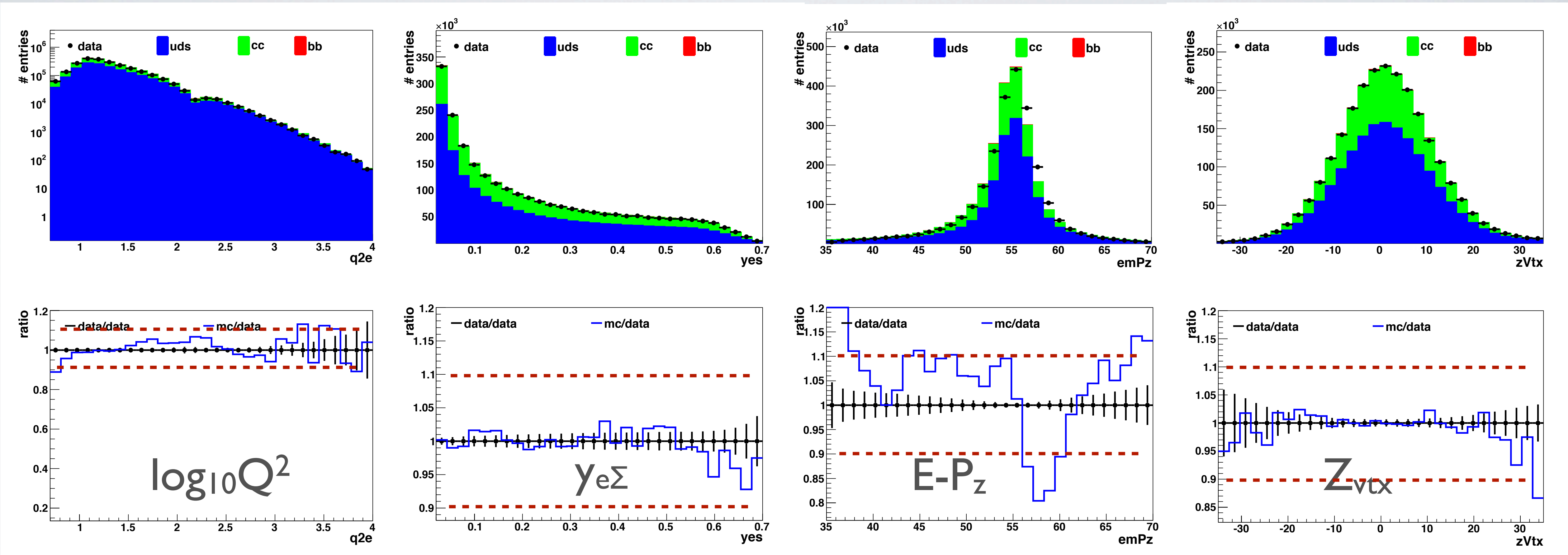
$\Theta_{track}(p_T > 200$ MeV) charged multiplicity P_T-Balance P_T^* of leading jet



☞ MC needs to be re-weighted in $P_{T(max)}$(Jet) (to start with)



INCLUSIVE SAMPLE (RE-WEIGHTED)



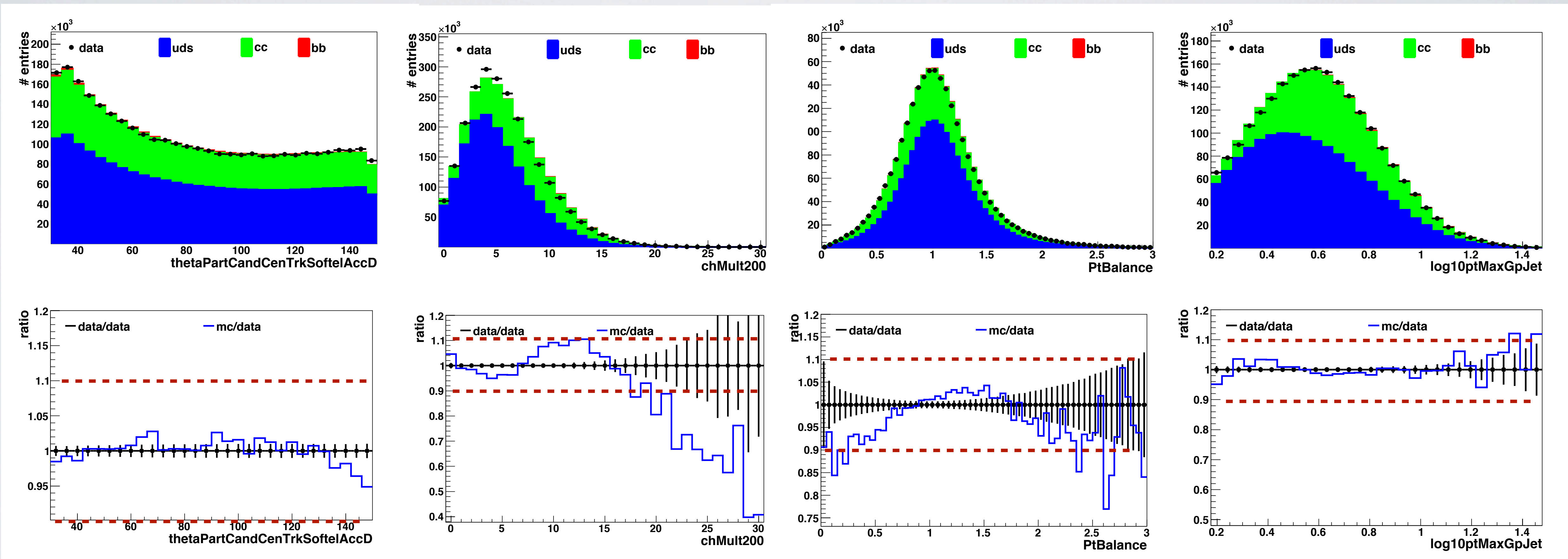
After Z_{vtx} correction and two iteration of re-weighting of **y_{GKI}** and **P_T^* of leading jet on hadron level**:

$y_{e\Sigma}$ and Q_e^2 improved but $E\text{-}P_Z$ far from optimal (may be critical since good understanding of HFS in mandatory for this analysis)

±10%

INCLUSIVE HFS AND JETS (RE-WEIGHTED)

$\Theta_{track}(p_T > 200$ MeV$)$ | charged multiplicity | P_T-Balance | P_T^* of leading jet



After Z_{vtx} correction and re-weighting iteratively in y_{GKI} (2x) and P_T^* **of leading jet** on hadron level (3x)

→ significant improvement of Θ_{track} and P_T^* of leading jet

±10%

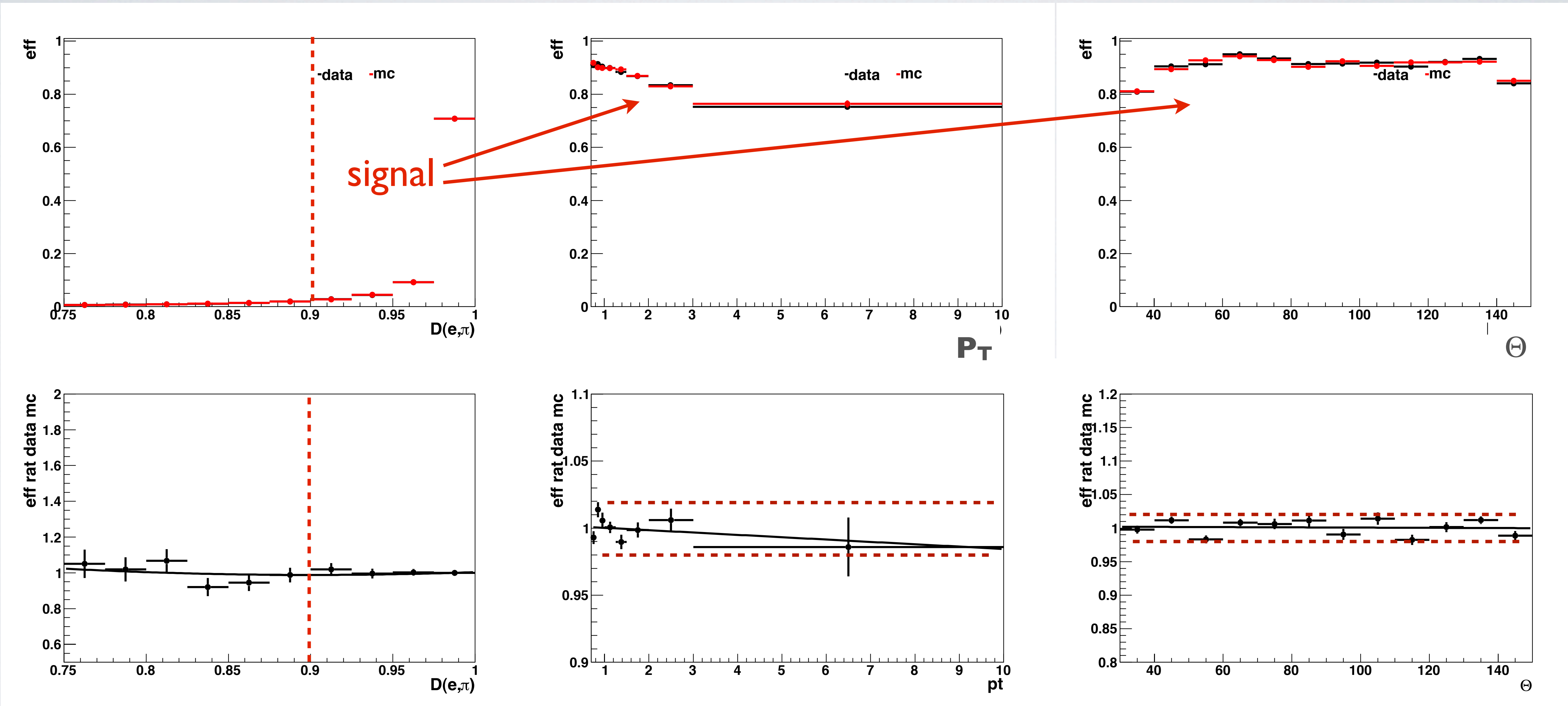
SOFT ELECTRON DISCRIMINATOR

The responds of the discriminator to particles in data and MC may differ → has been checked / calibrated (iterative correction procedure)

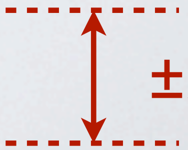
electron efficiency using photon conversions
hadron misidentification using K^0_s for pions and Λ for protons

Π-E DISCRIMINATOR EFFICIENCY FOR ELECTRONS

Discriminator output $P_{T,track}$ Θ_{track}

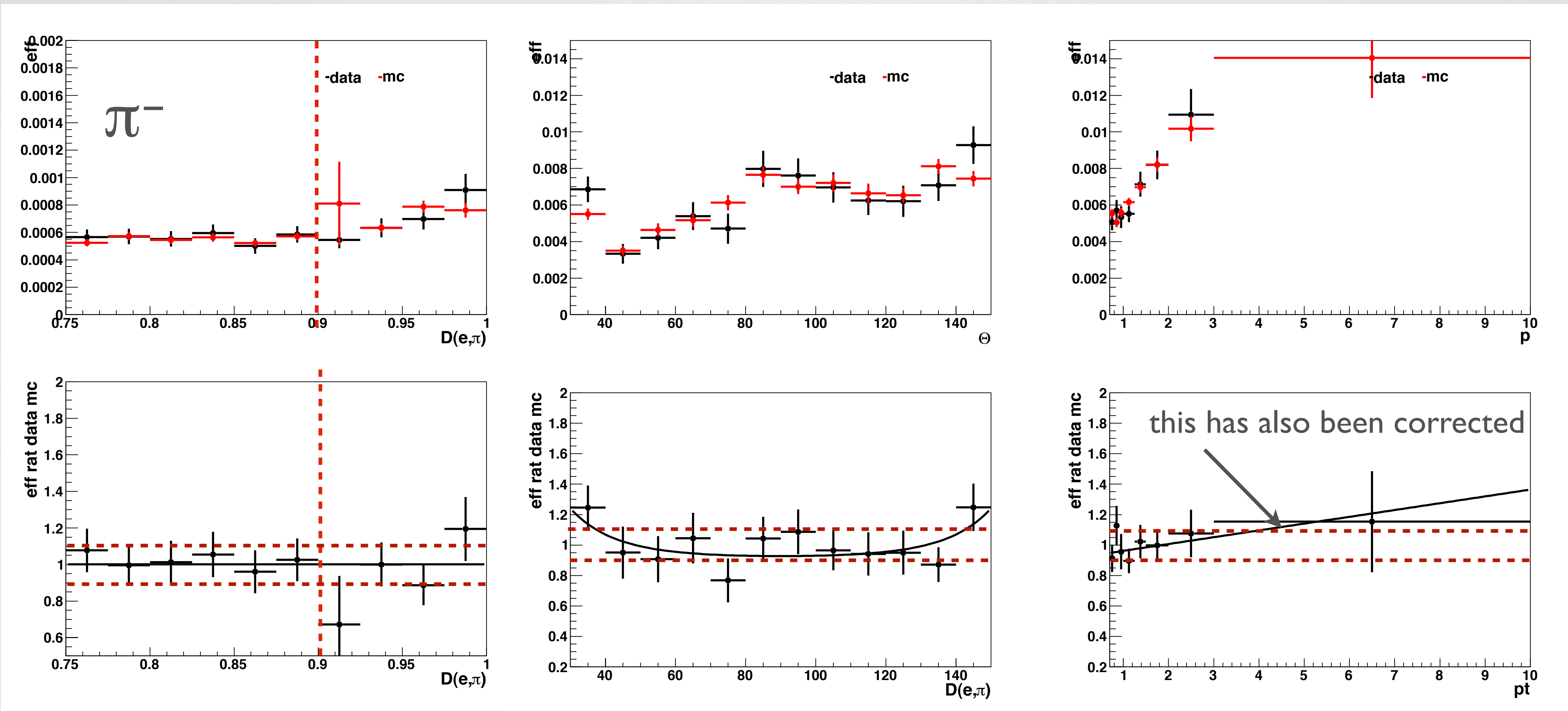


After calibration efficiencies for data and MC agree within 2%
Similar results are obtained for the p-e discriminator



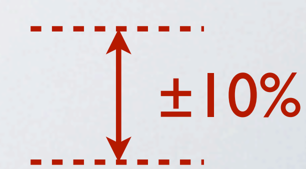
MISIDENTIFICATION OF PIONS

Discriminator output Θ_{track} P_{track}

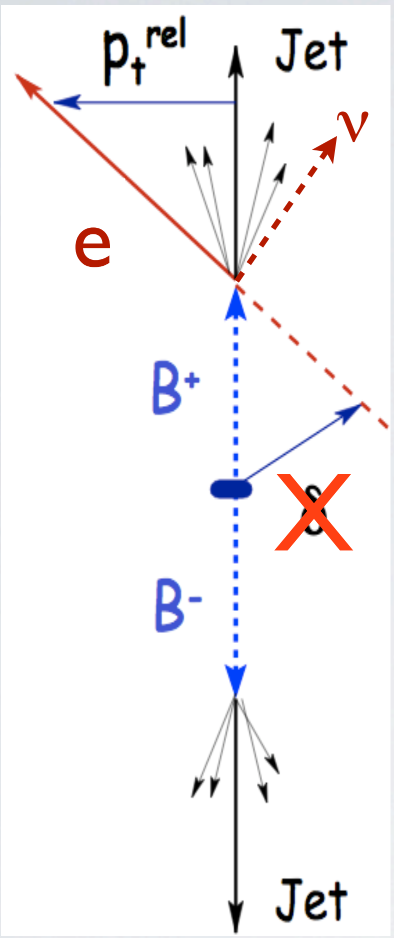


After calibration discriminator response for pions for data and MC agree within statistical uncertainties

Pion misidentification probability is 0.0028(0.0036) for $\pi^{-}(\pi^{+})$

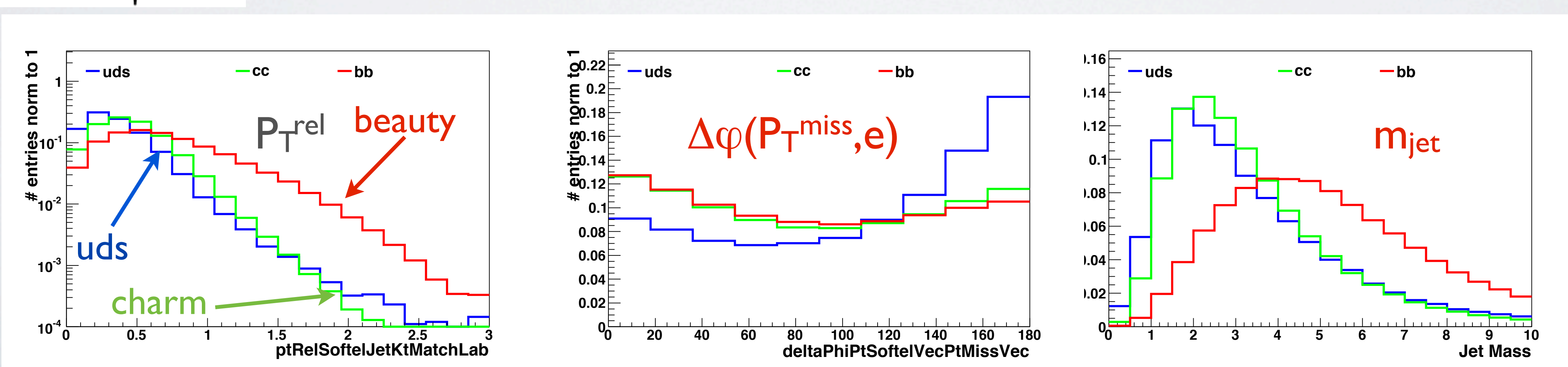


VARIABLES DISCRIMINATING UDS, C AND B

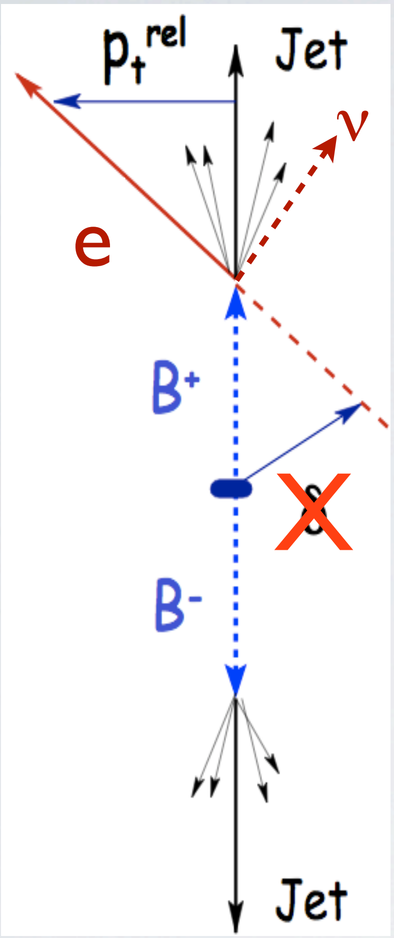


Only variables that have not sensitive to the re-weights can be used for discriminating uds, charm and beauty:

- P_T^{rel}
- soft electron discriminator output (D_{ele})
- angle in r-φ between P_T^{miss} and soft electron (Δφ)
- jet mass (m_{jet})



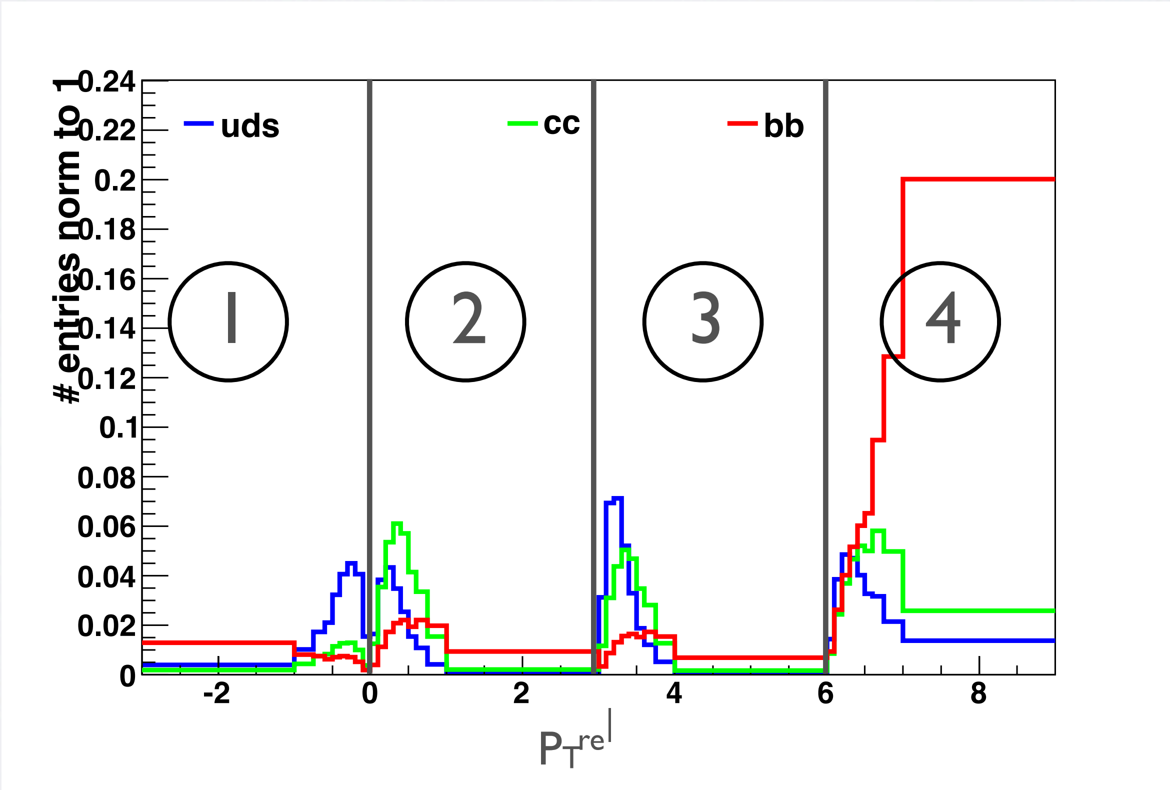
TEMPLATE FITS



Templates: uds, charm($c \rightarrow e$, fakes), beauty($b \rightarrow e$, $b \rightarrow c \rightarrow e$, fakes) Use TUNFOLD

Main variable: P_T^{rel} measured in 4 regions:

- (1) 0.825(0.75) $< D_{ele} < 0.9$ (for hadrons - set to $-P_T^{rel}$)
- (2) $D_{ele} \geq 0.9$, $\Delta\varphi < \pi/2$, $m_{jet} < 3.5$ GeV (charm enhanced)
- (3) $D_{ele} \geq 0.9$, $\Delta\varphi > \pi/2$, $m_{jet} < 3.5$ GeV (uds enhanced, +3)
- (4) $D_{ele} \geq 0.9$, $3.5 < m_{jet} < 10$ GeV (beauty enhanced, +6)

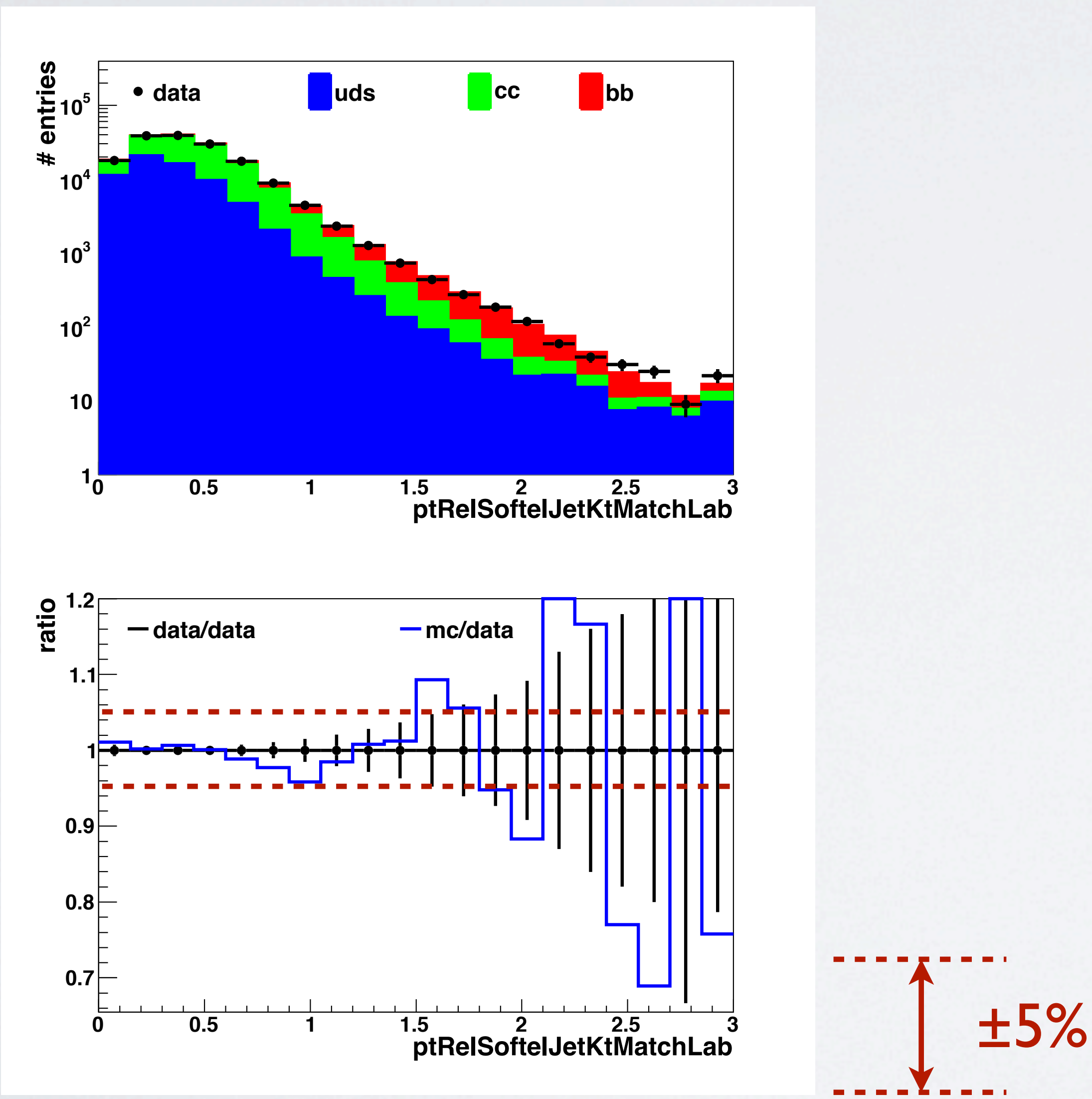


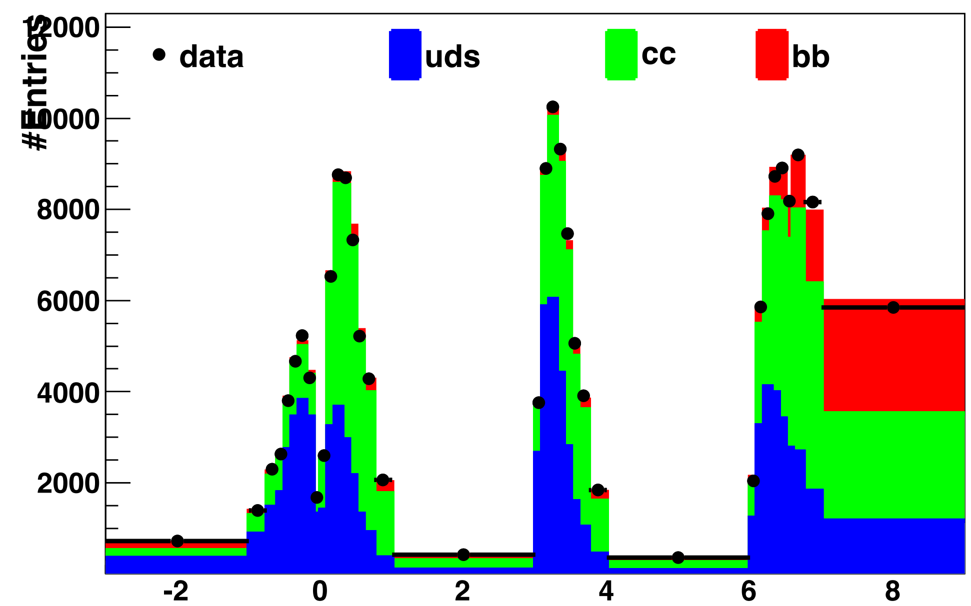
FIT FOR VISIBLE PHASE SPACE

Visible phase space:

5 GeV^2 < Q^2 < 2000 GeV^2, 0.02 < y < 0.7

0.7 GeV < P_T^e <25 GeV, -1.3 < η_e <1.3





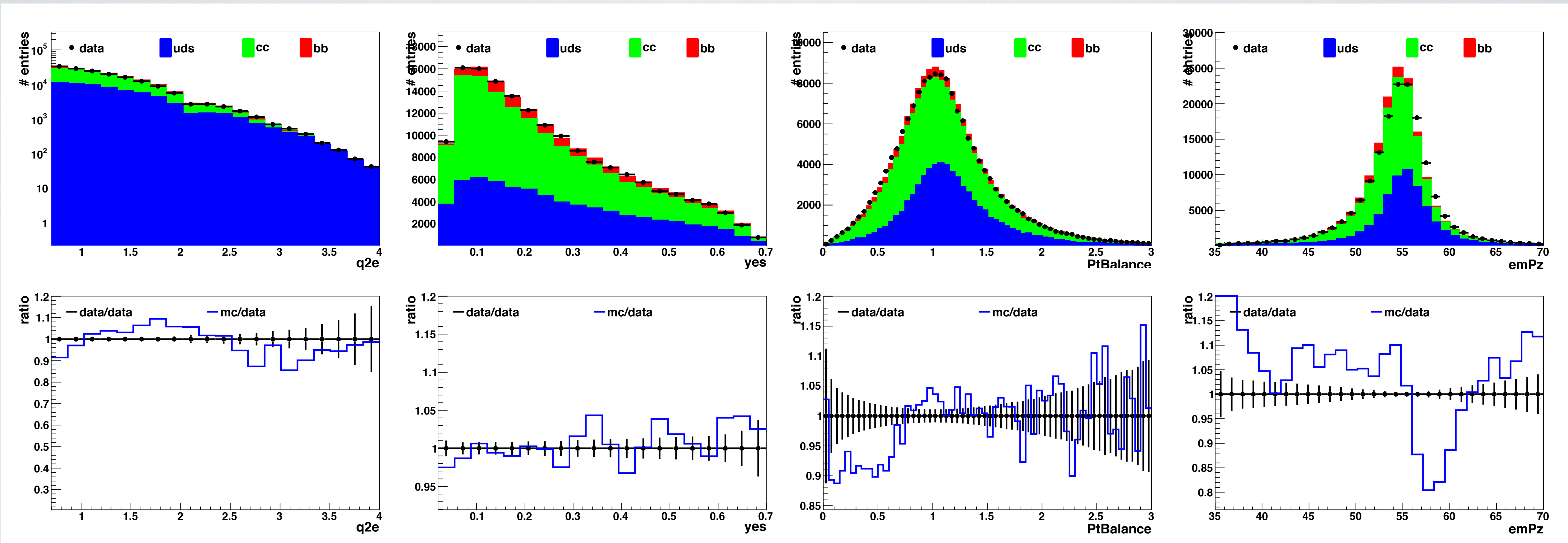
flavour type	frac. before fit	frac. after fit
uds	0.165	0.409 +/- 0.003
cc	0.791	0.521 +/- 0.005
bb	0.044	0.071 +/- 0.002

NDF = 33

χ^2 = 43.4

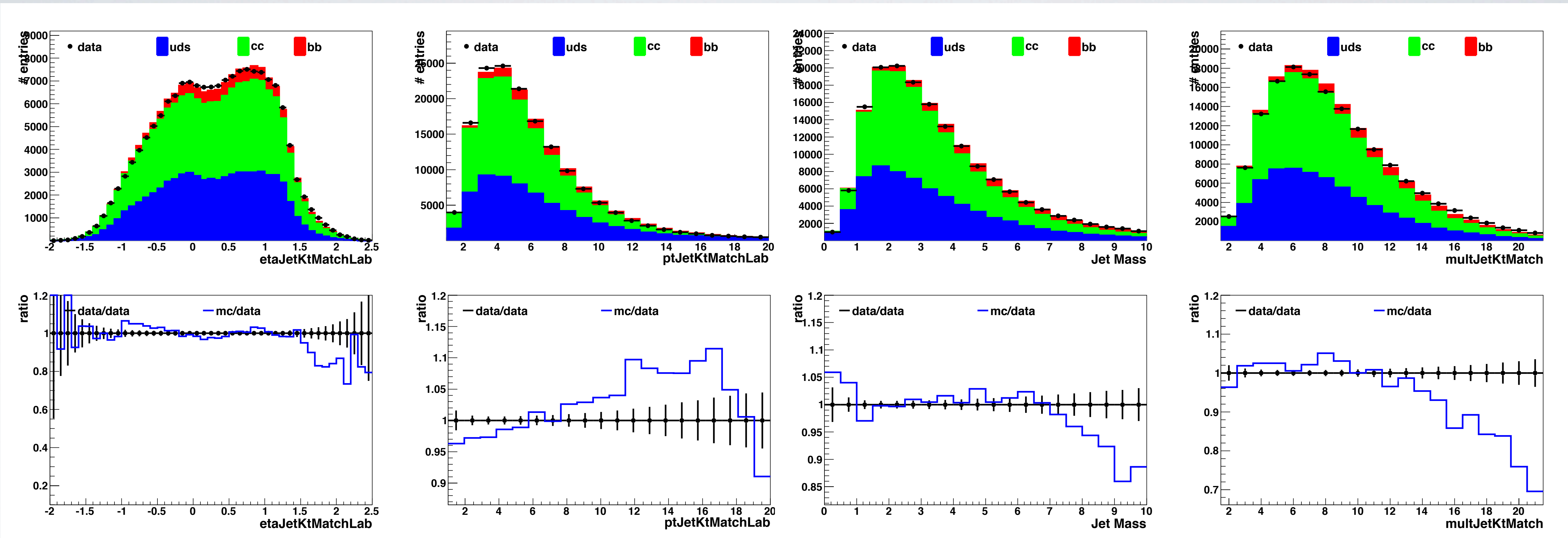
CONTROL DISTRIBUTIONS - I-EVENTS

$\log_{10}Q^2$ | $y_{e\Sigma}$ | P_T-Balance | $E-P_z$



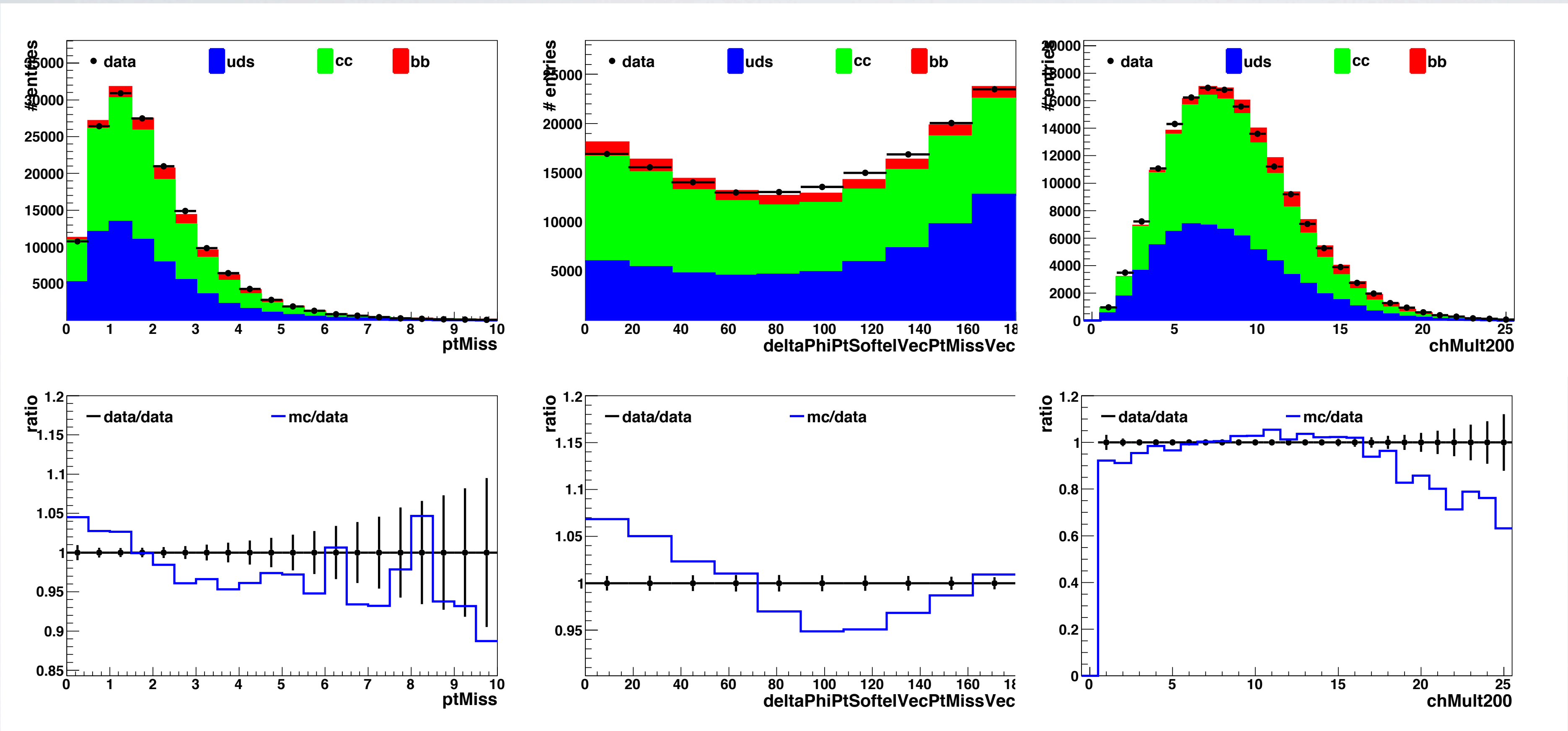
CONTROL DISTRIBUTIONS - II-JETS

η^{jet} P_T^{jet} m^{jet} particles in jet



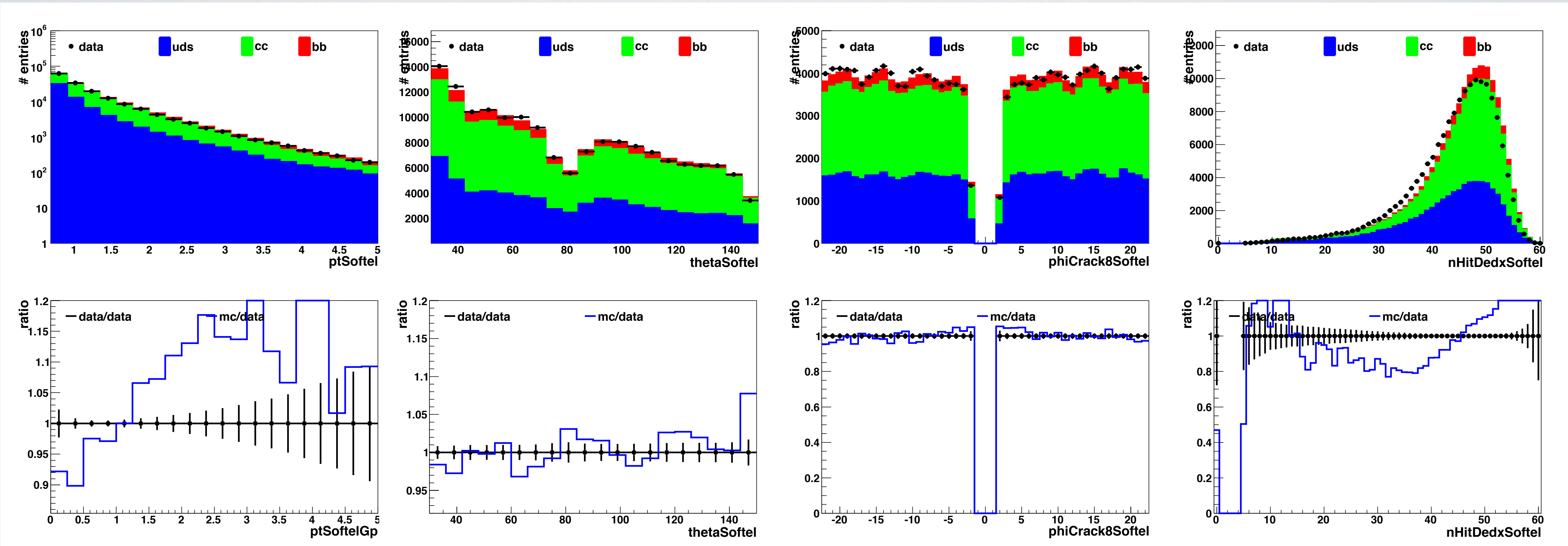
CONTROL DISTRIBUTIONS - III-HFS

P_T^{miss} $\Delta\varphi(e, P_T^{miss})$ $n_{ch}(P_T<0.2GeV)$

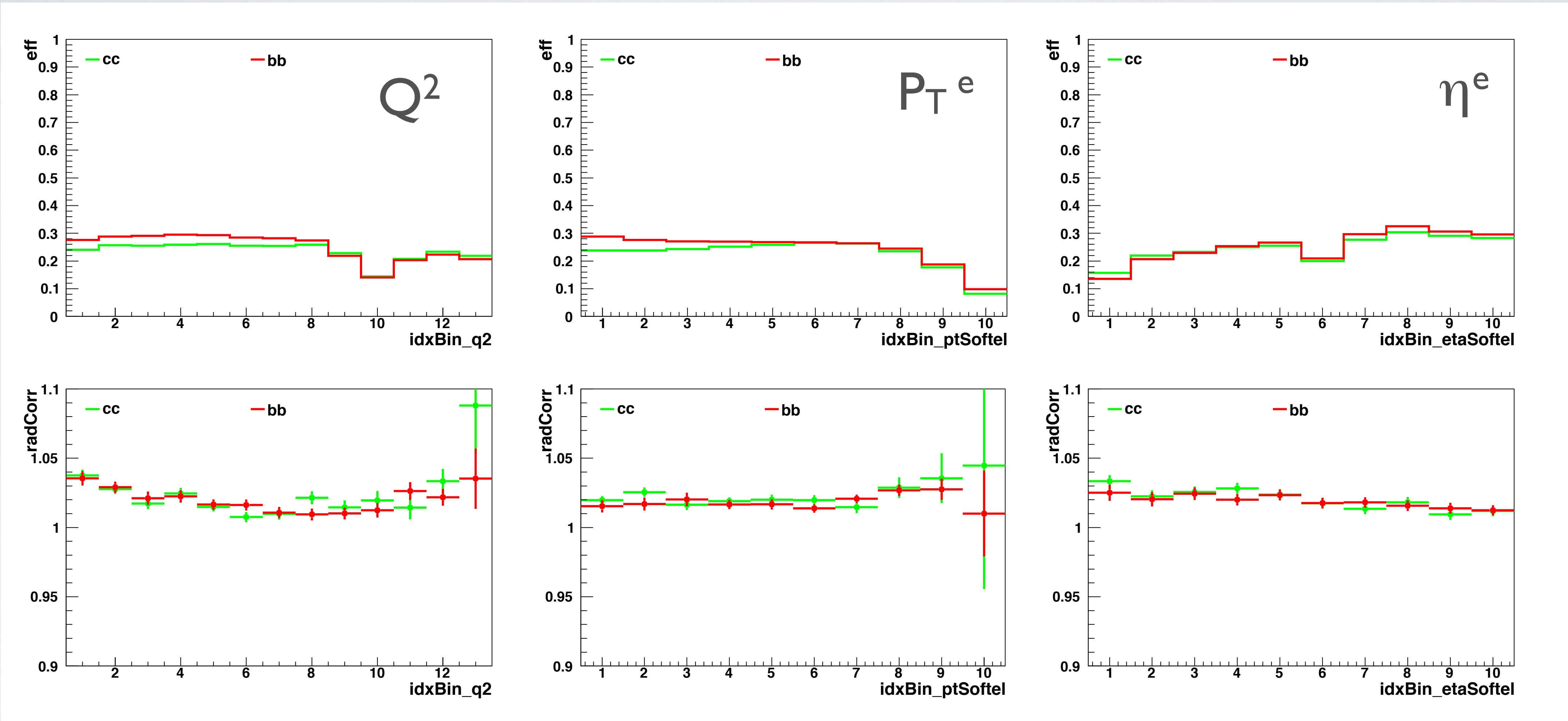


CONTROL DISTRIBUTIONS - IV-ELECTRON

P_T^{e} Θ^e φ^e_8 $n_{dE/dx}$



EFFICIENCIES & RADIATIVE CORRECTION



Similar efficiencies for electrons from charm and beauty (≈25%)
Similar radiative corrections which are small (check α_{em})

HVQDIS

Decays to electrons implemented in HVQDIS:

D→eνX: using electron decay spectrum extracted from CLEO measurement

Branching fraction: c→eνX=0.098

Beauty:

B→eνX: using electron decay spectrum extracted from Belle measurement

B→DX: decay spectrum from MC and D→eνX as for charm from CLEO

B→τνX→eνννX: not implemented yet

B→J/ψX→eeX: not implemented yet

Branching fraction: b→eνX=0.2238 including corrections for τνX and J/ψX and for getting two electrons from the same b-quark

CROSS SECTION - VERY FIRST LOOK

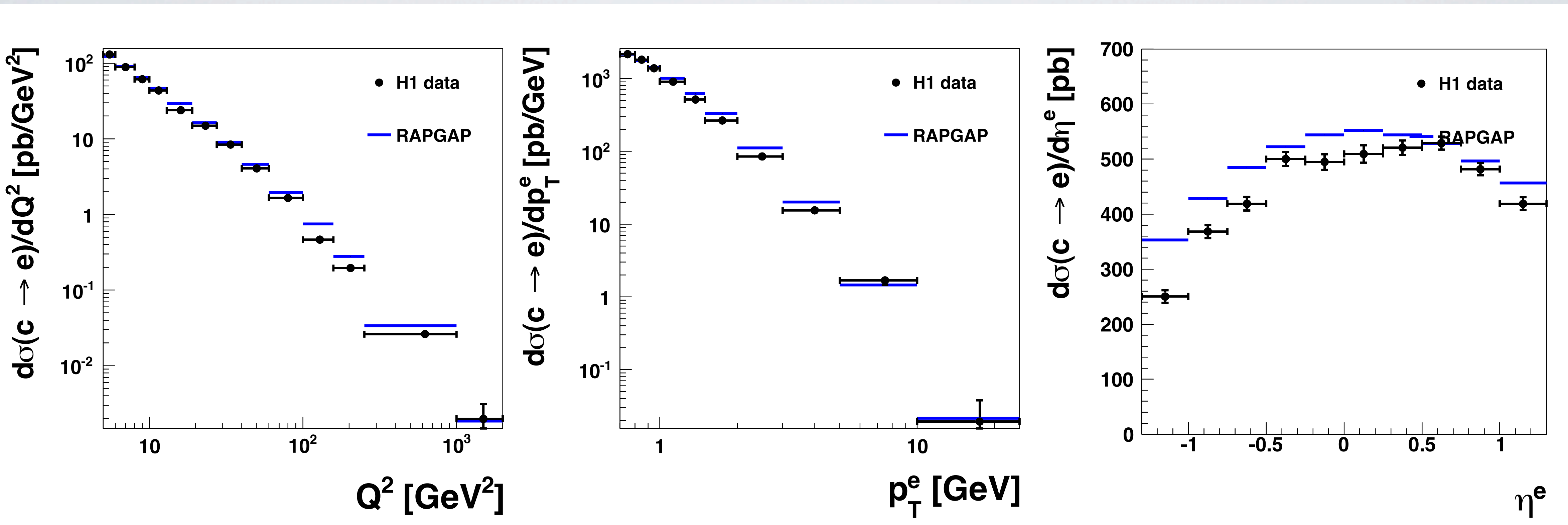
Visible phase space:
5 $GeV^2 < Q^2 < 2000\ GeV^2$, $0.02 < y < 0.7$

0.7 GeV $< P_T^e <$ 25 GeV, $-1.3 < \eta_e < 1.3$

	Charm	Beauty
Data	1151±10 pb	147.4±4.3 pb
Rapgap CTEQ6L	1268 pb	95 pb
HVQDIS CTEQ5F3 m_{low}	1176 pb (m_c=1.35)	105 pb (m_b=4.50)
HVQDIS CTEQ5F3 m_{high}	965 pb (m_c=1.35)	79 pb (m_b=5.00)

Statistical errors only
Charm cross section stable against variations: O(2%)
Beauty cross section is 1.5x larger than HVQDIS and Rapgap

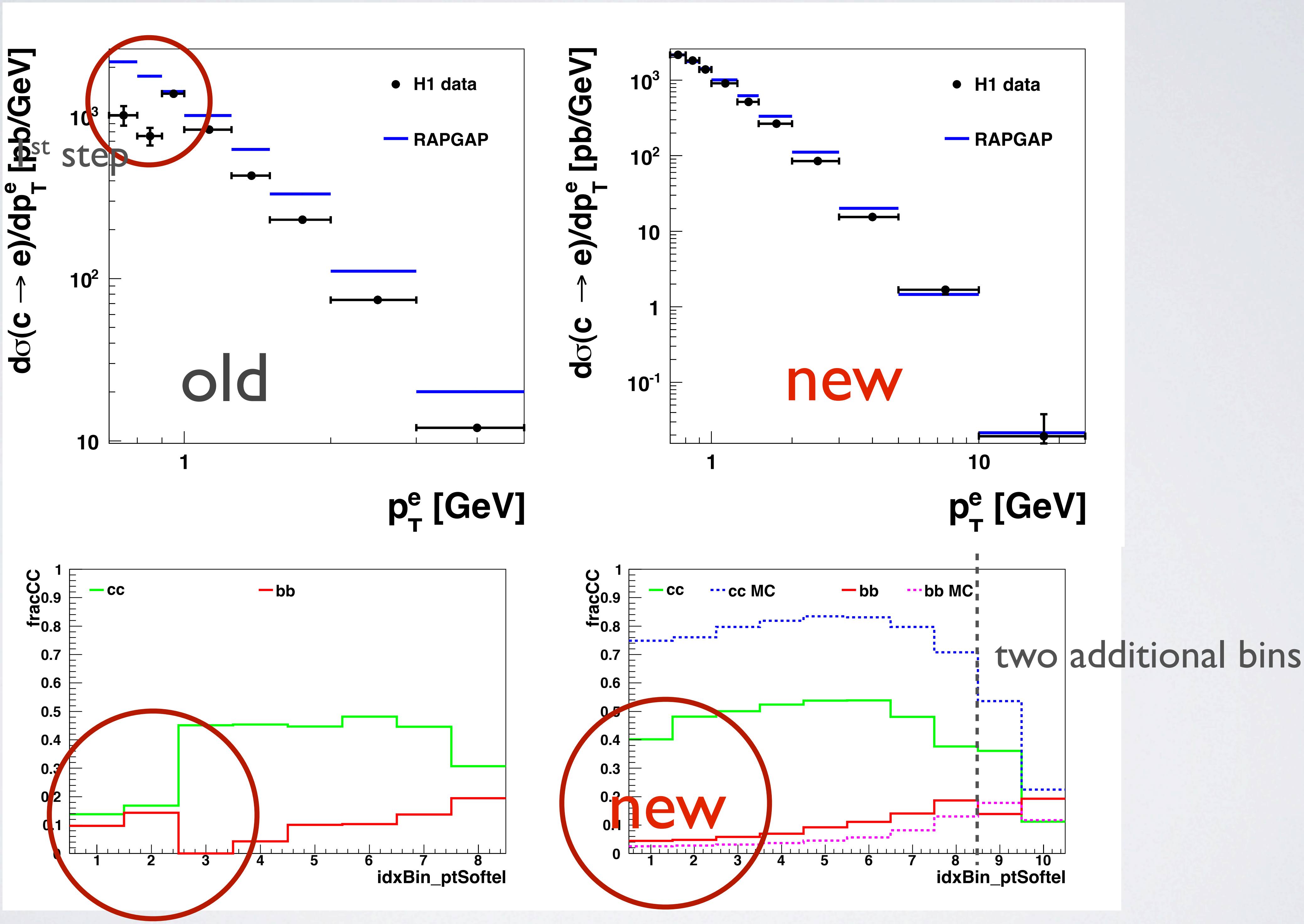
CHARM CROSS SECTION VS. RAPGAP



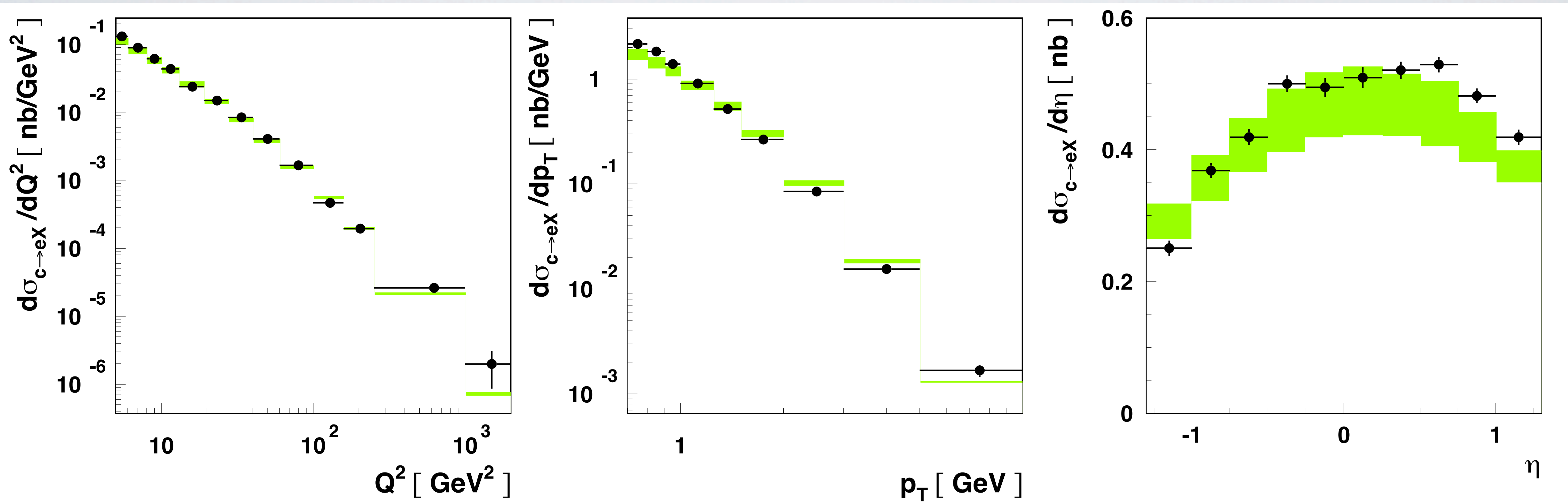
Statistical errors only

Reasonable agreement between data and Rapgap

LAST PLOTS FROM MARTIN VS CURRENT STATUS



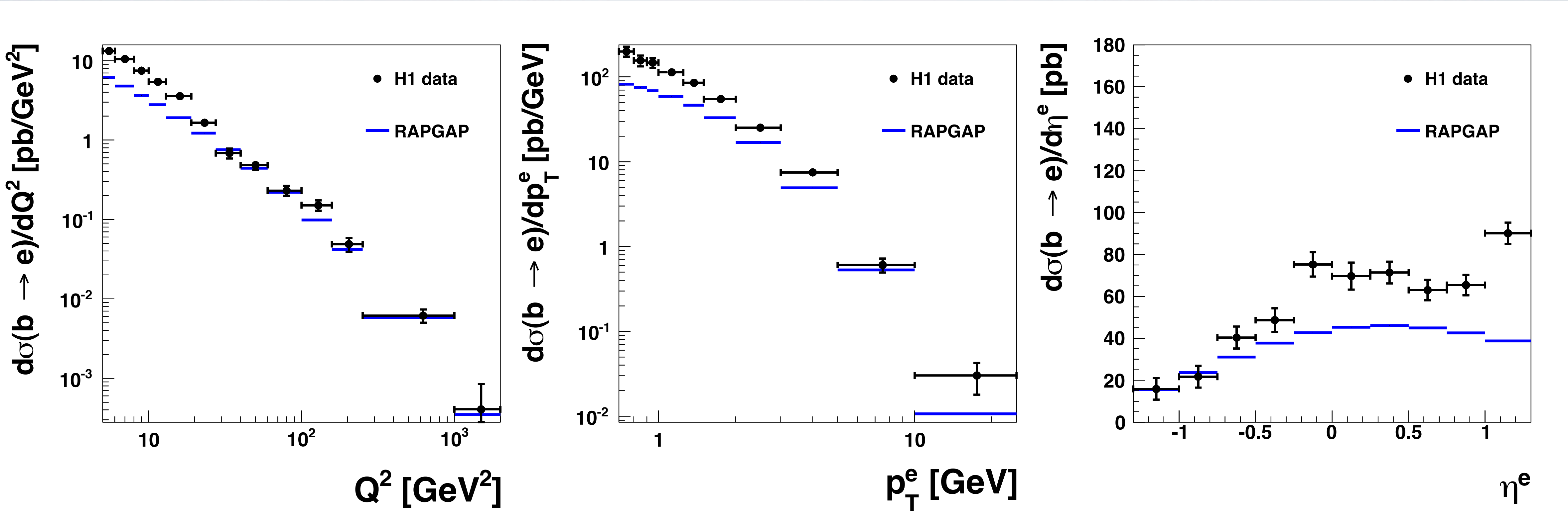
CHARM CROSS SECTION VS. HVQDIS



Statistical errors only - band on HVQDIS: m_c variation

Reasonable agreement between data and HVQDIS

BEAUTY CROSS SECTION VS. RAPGAP



Statistical errors only

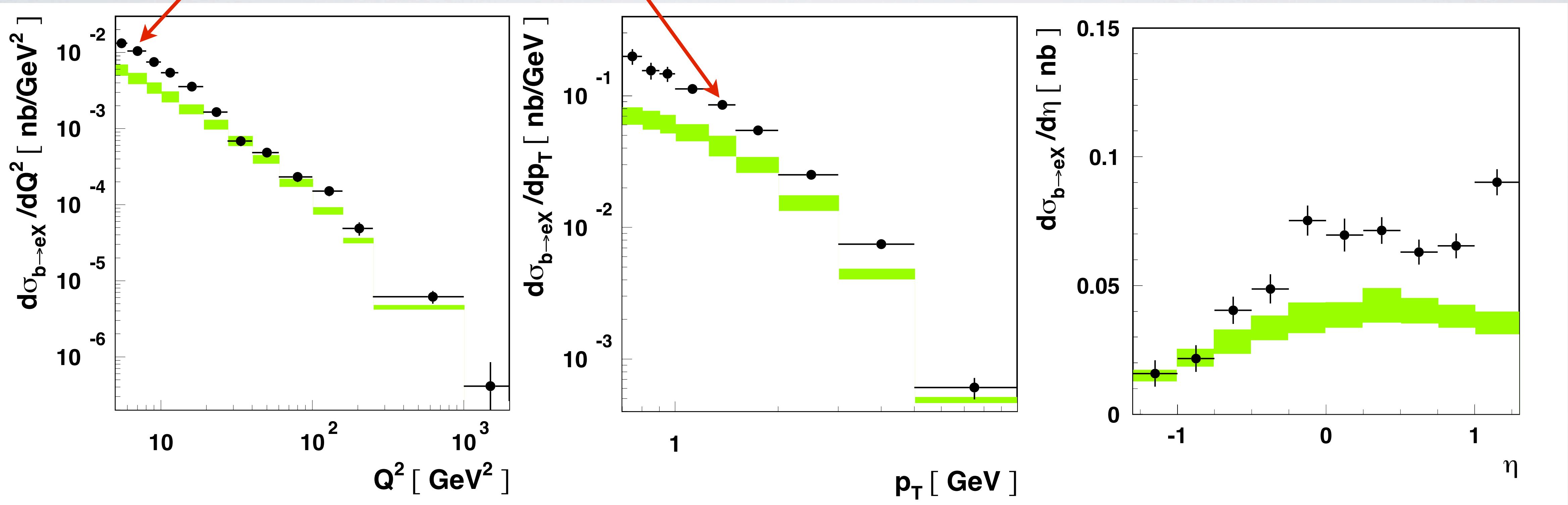
Reasonable agreement between data and Rapgap for Q^2>20 GeV2

Significant deviations at small Q^2, P_T and forward η

Don't forget: This is the first shot

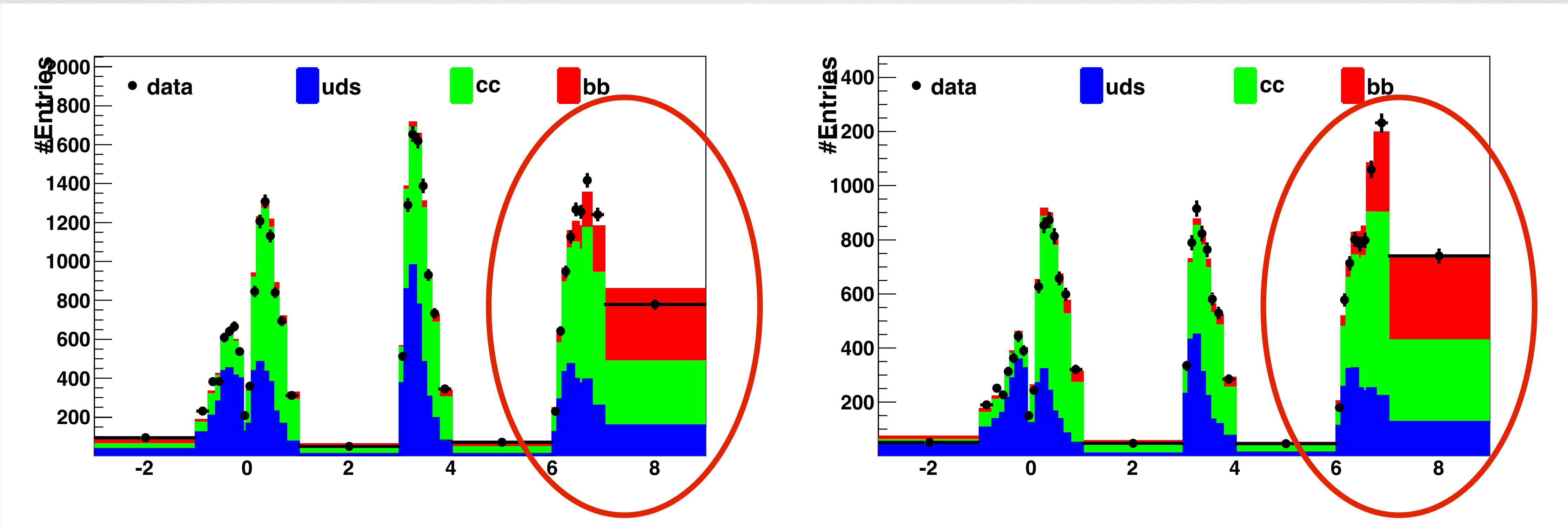
BEAUTY CROSS SECTION VS. HVQDIS

let's have a closer look
(smallest errors)



Statistical errors only - band on HVQDIS: m_b variation
Same features w.r.t. HVQDIS observed than for Rapgap

BEAUTY - A CLOSER LOOK



charm is not able to accommodate for the excess observed at large values of m_{jet} and P_T^{rel} - needs more investigations

BEAUTY CROSS SECTION IN ZEUS PHASE SPACE

Visible phase space:
$Q^2 > 10$ GeV^2, $0.05 < y < 0.7$

0.9 GeV $< P_T{}^e < 8$ GeV, $-1.5 < \eta_e < 1.5$

	$b \rightarrow e\nu X$
ZEUS	$71.8 \pm 5.5_{stat}(+5.3/-5.5)_{sys}$ pb
this analysis	86.4 ± 3.3 pb

CONCLUSIONS

- Analysis of c/b→electrons continues - most of the steps checked
- Studies of inclusive DIS and inclusive jets in DIS showed the need for re-weighting MC in y and $P_{T,max}^{jet}$
- Significant improvement in describing the soft electron sample after applying re-weights deduced from the inclusive samples
- Better understanding of the HFS still needed
- Many issues presented last time are solved
- Additional observables with c/b discriminating power found (next step: multivariate analysis)
- c→eX and b→eX implemented in HVQDIS (needs to be refined)
- First look on cross sections revealed a reasonable description of the charm data but beauty turns out to be about 50% above the predictions from Rapgap and HVQDIS (need to be investigated)

BACKUP

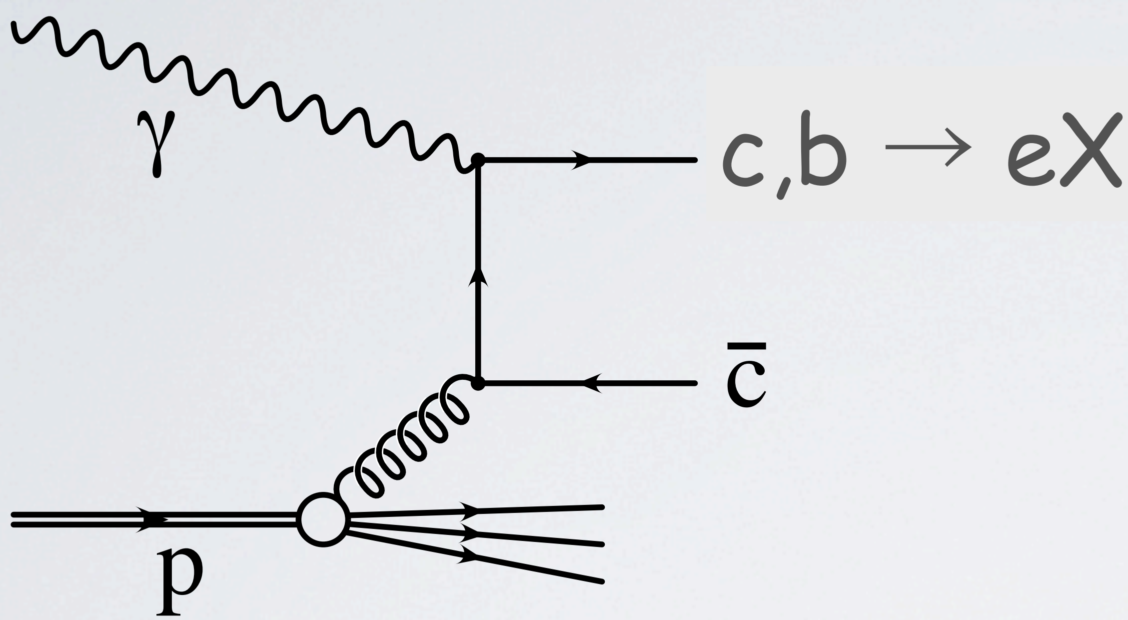
CHARM & BEAUTY WITH ELECTRONS

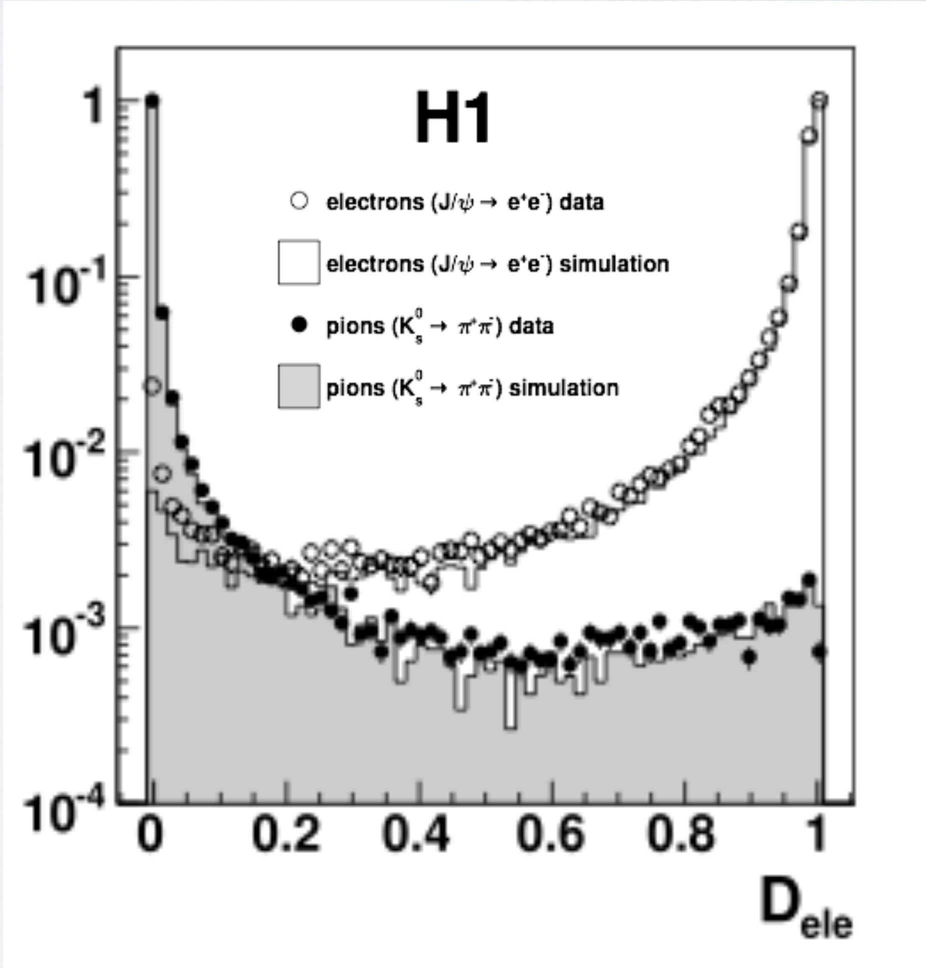
Martin Brinkmann, Karin Daum

This is all based on Martin's code

- Motivation
- Last stage of Martin's analysis
- Current status

MOTIVATION - AIM OF THIS ANALYSIS





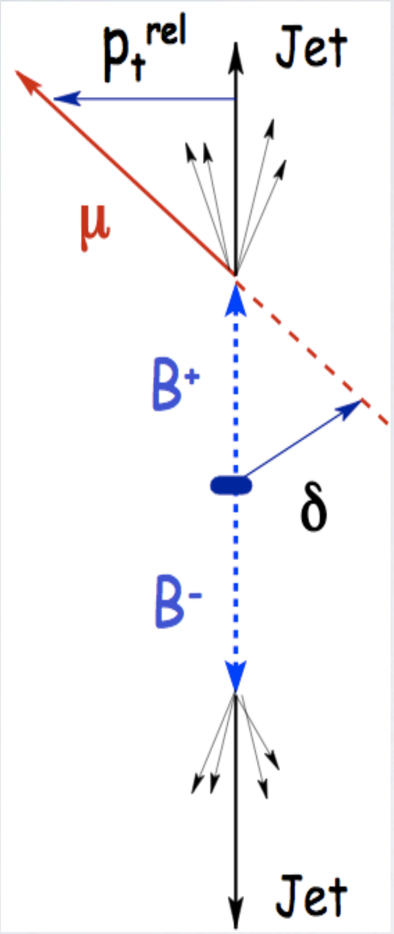
☞ We have an excellent e/π discriminator

π-suppression by a factor 300!

☞large leptonic branching fractions for c/b

☞keep analysis orthogonal to other measurements to profit from combination

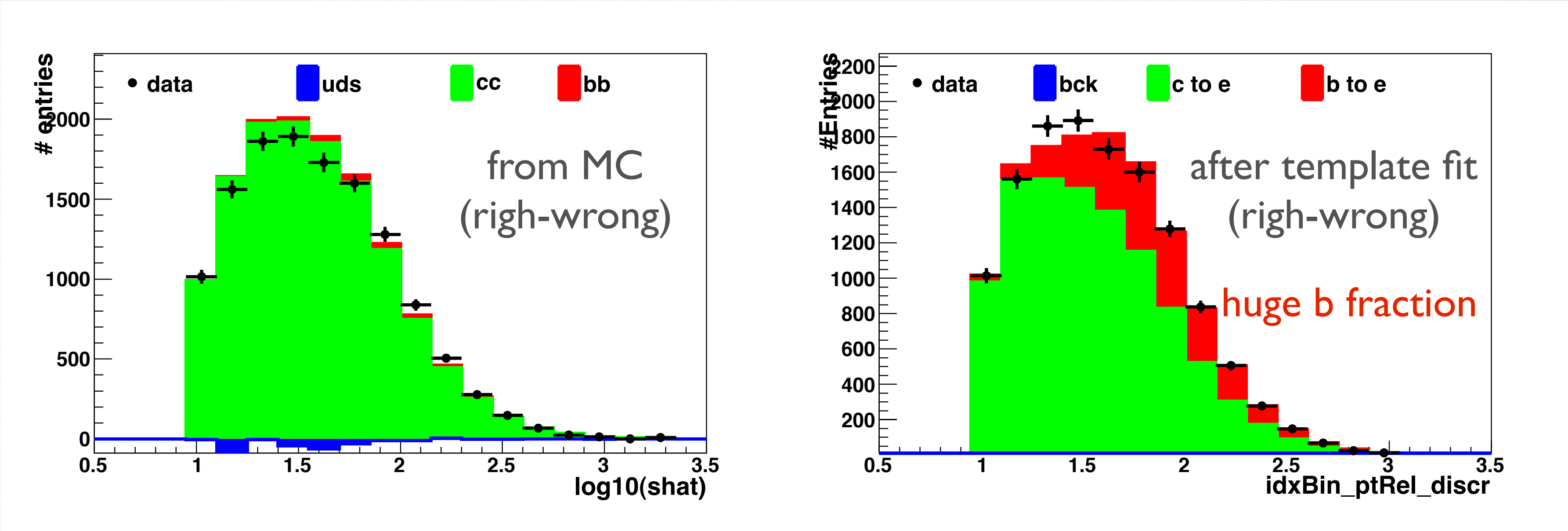
METHOD & COMPLICATIONS



Orthogonality w.r.t. other analyses constrains the choice of observables ⇒ p_T^{rel}

Many observables discriminating between beauty and charm are not well described (Martin tried many - only p_T^{rel} seems reasonable)

Example from D*s: shat



Wednesday, 11 September 2013

MORE COMPLICATIONS

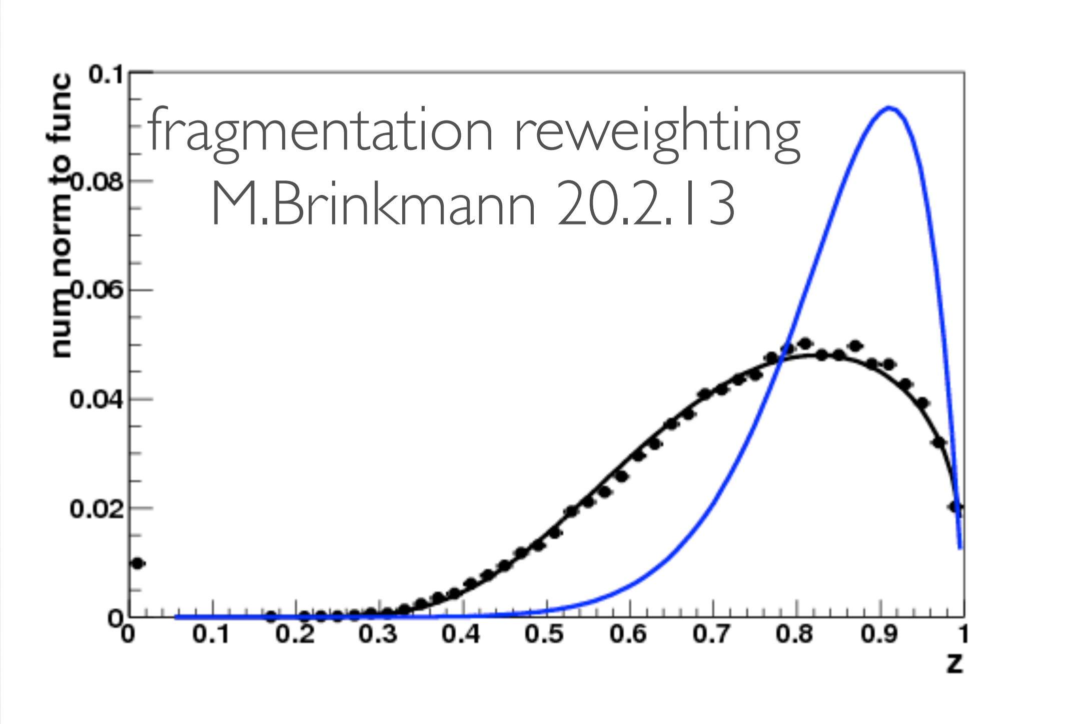
Need a good understanding of the π/e discriminator

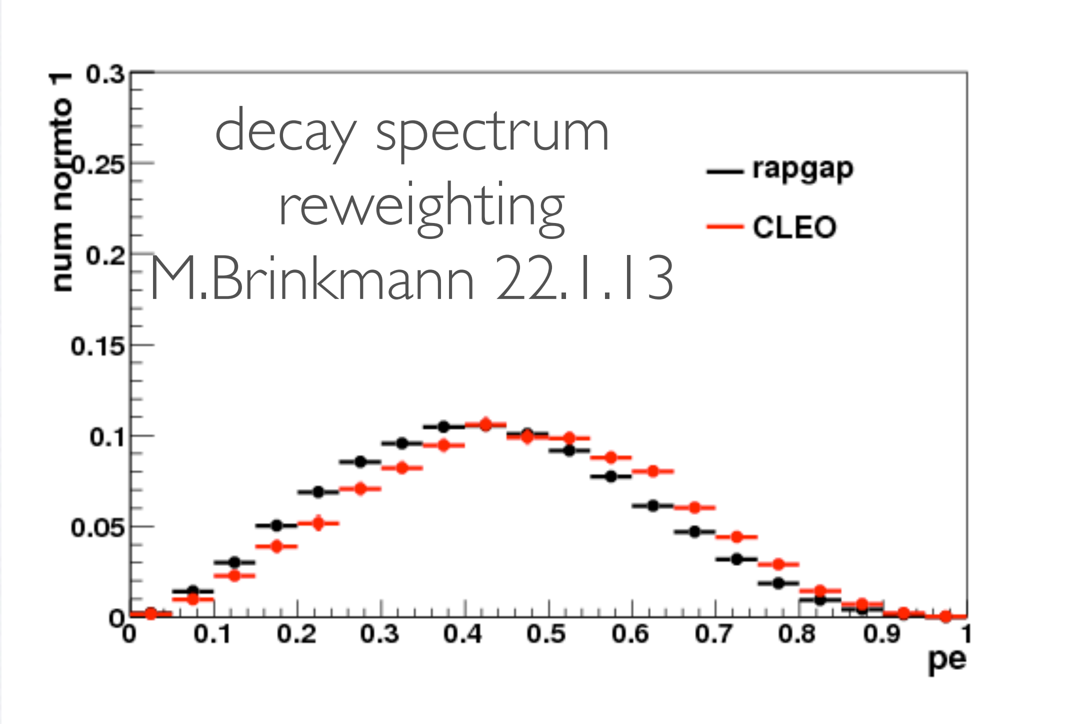
Need also an understood proton/electron discriminator

Need to reweight c-fragmentation

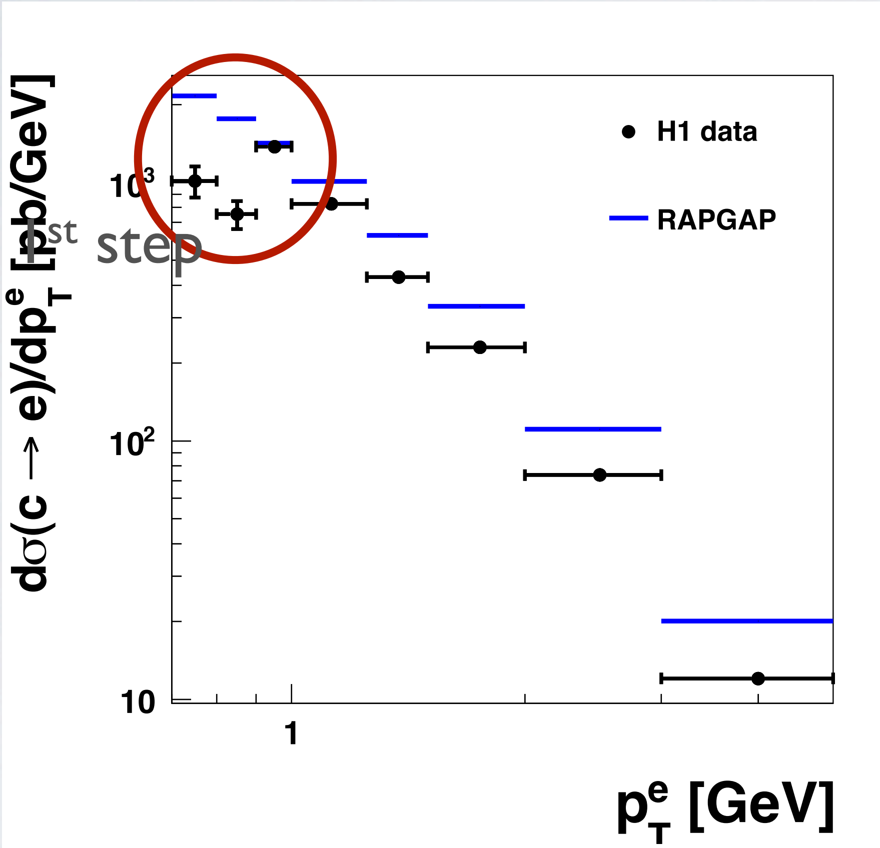
Need to reweight electron decay spectrum

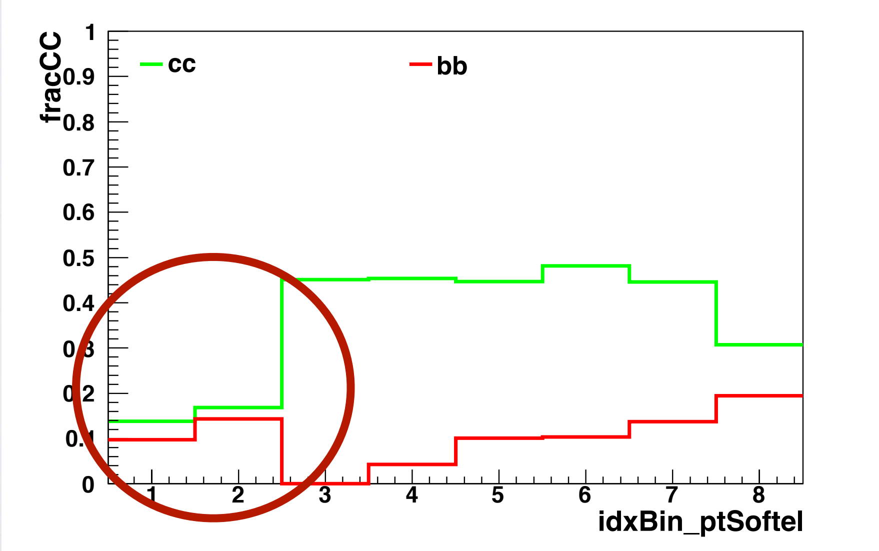
...





LAST PLOTS FROM MARTIN

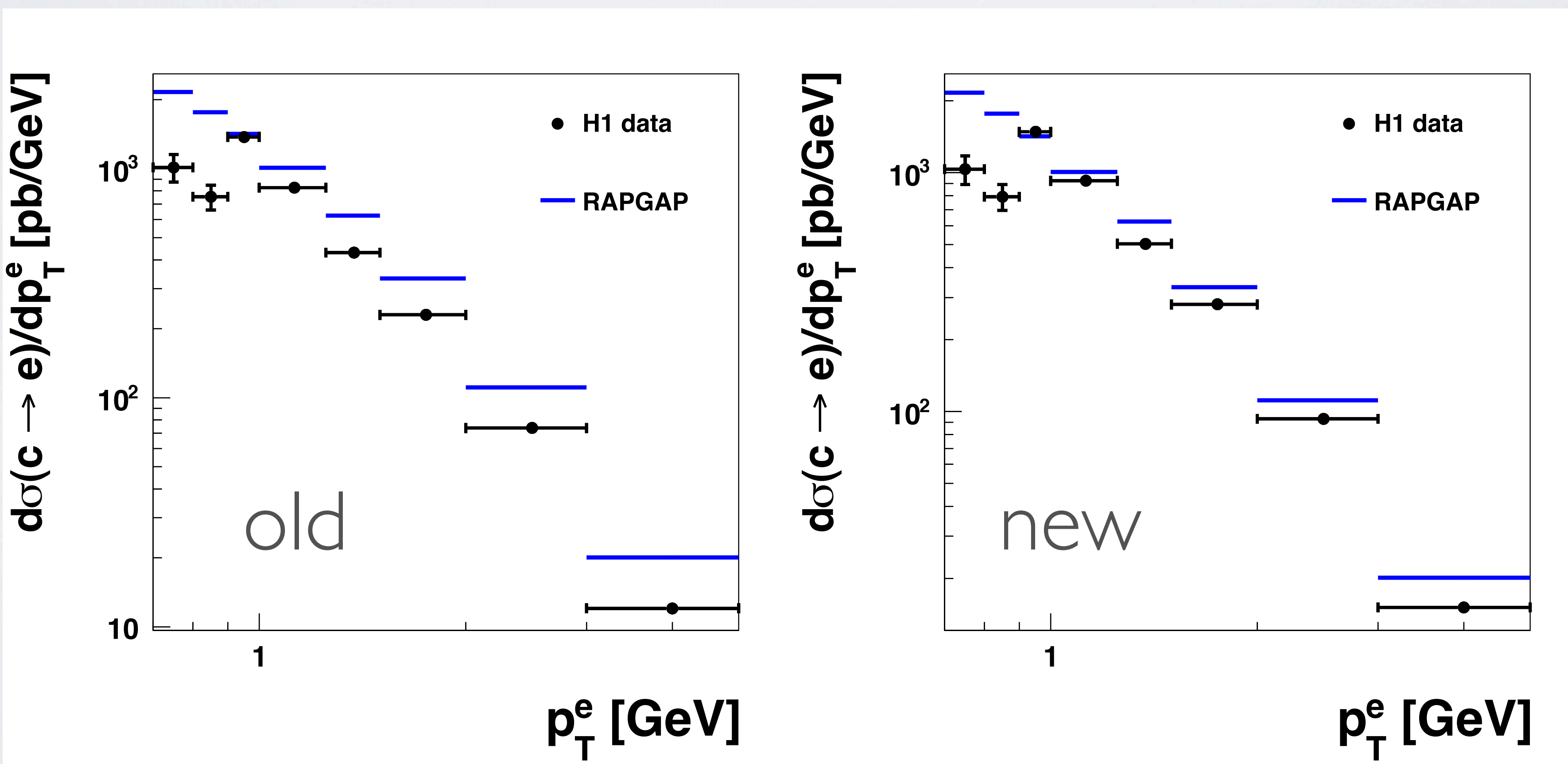




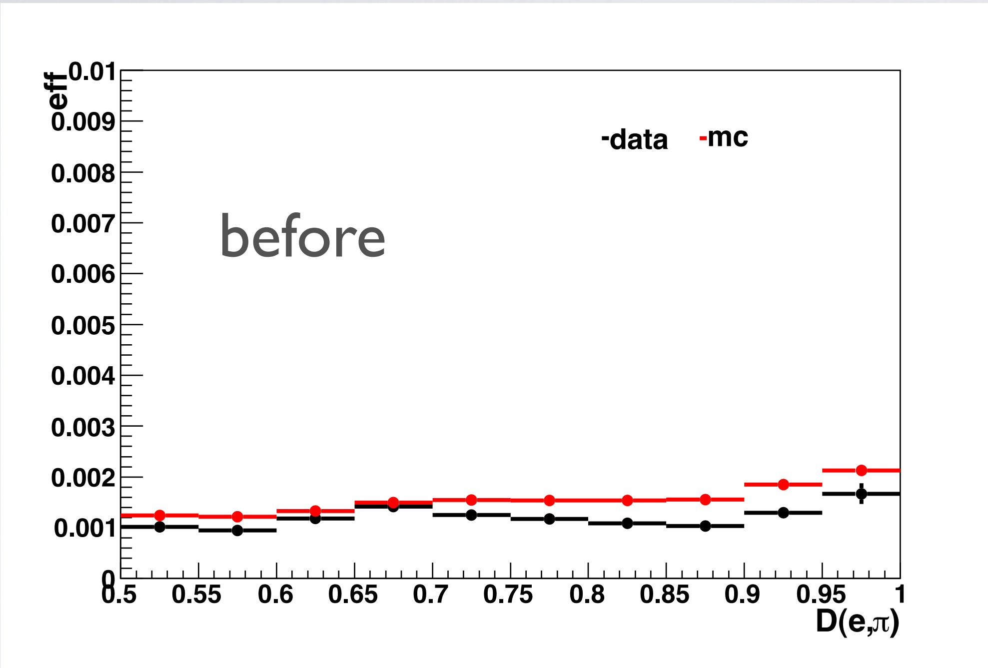
- Measured cross section: significantly below MC (opposite to D* and LT)
- step in cross section at low p_t - opposite behaviour for beauty
- strange result from fraction fit at low p_t (fit instable?)
- reason was not found

SINCE THEN

efficiency determination:
fragmentation and decay spectrum reweight was applied on detector level only
after correction: cross section increased but low p_t problem remains



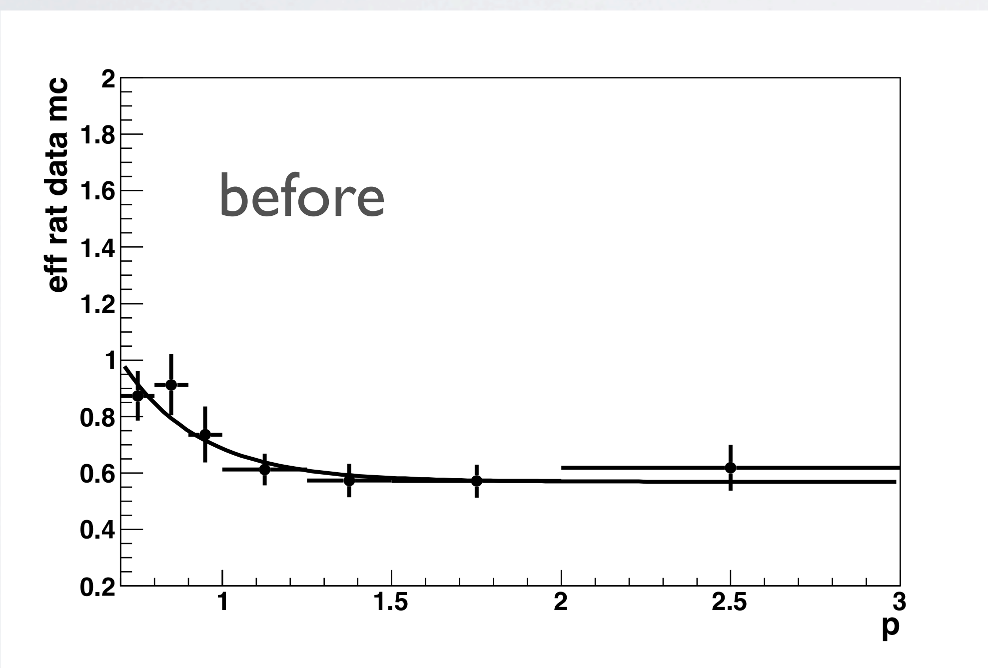
DISCRIMINATOR RESPONSE - PIONS FROM K^0

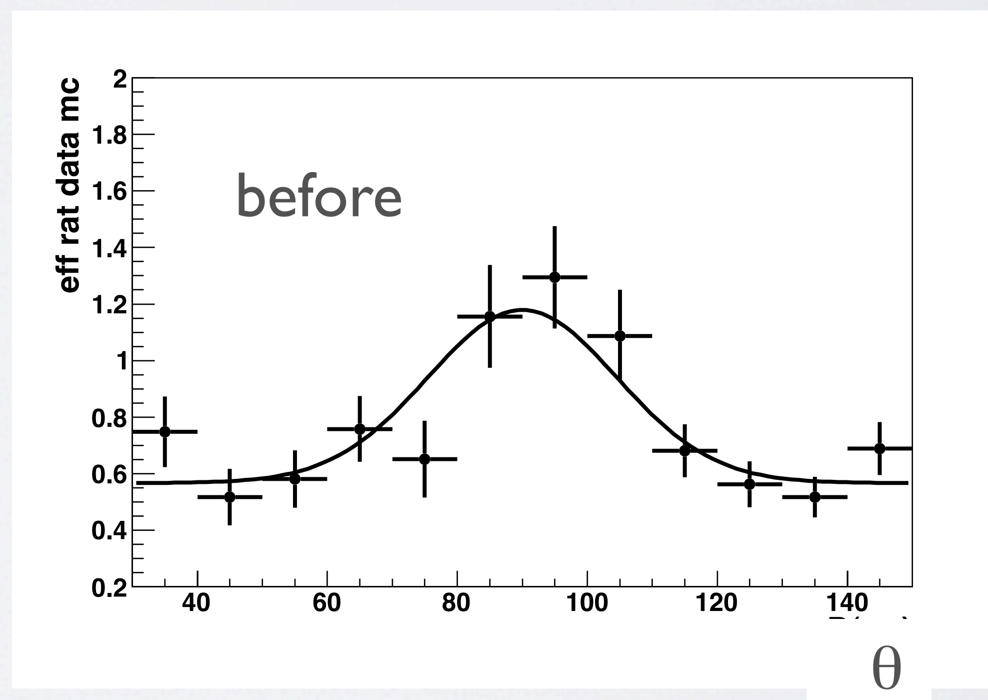


Differences visible $\approx 10^{-4}$!

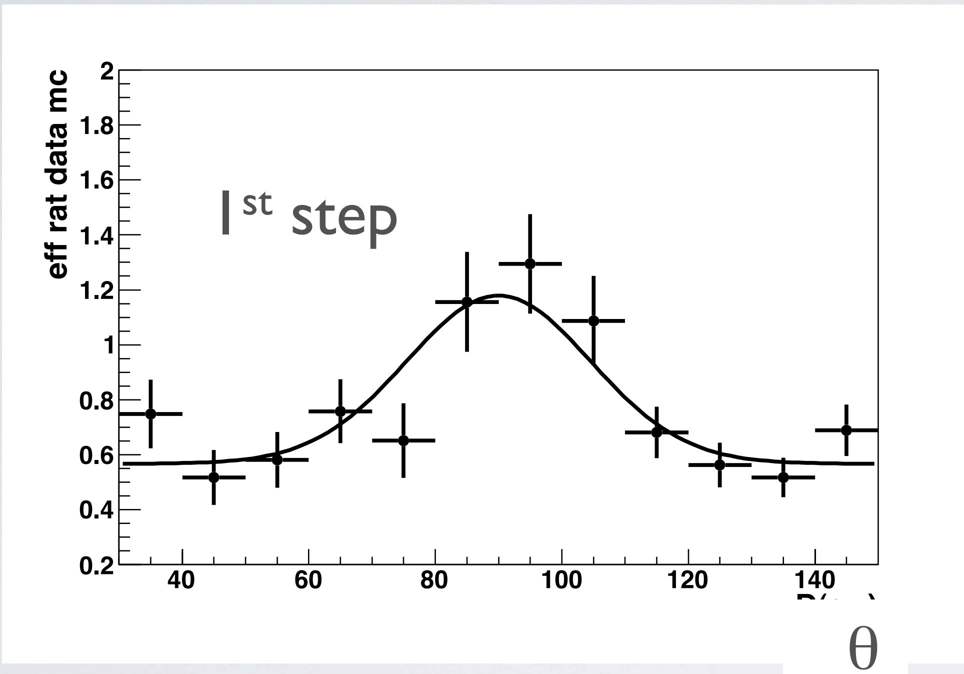
- corrections applied independently in θ and p (correlations!)

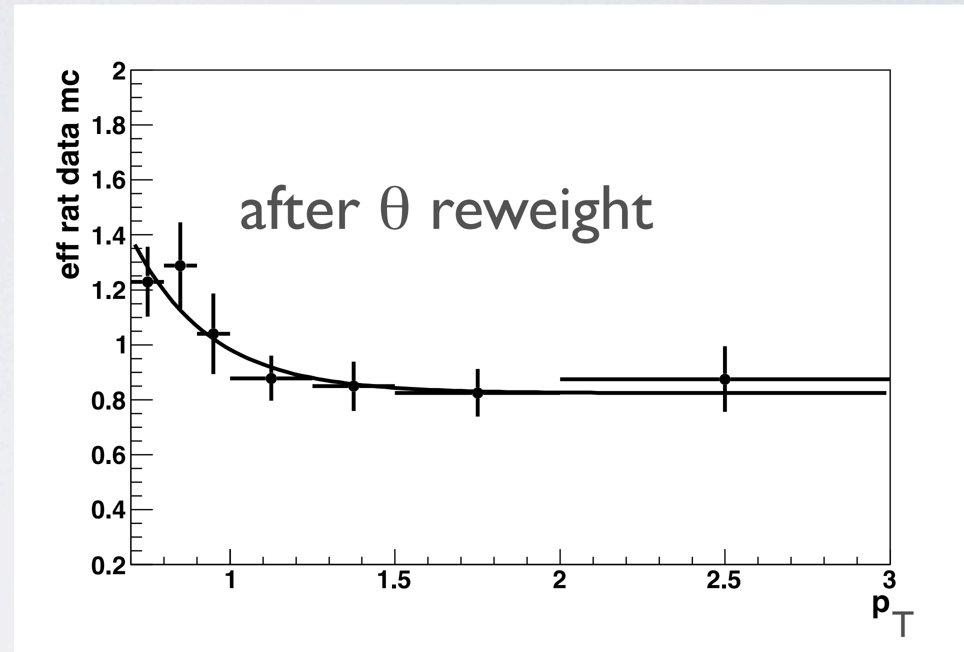
change to: θ and p_T (iterative) and improve $K^0(\Lambda)$ selection (LT)

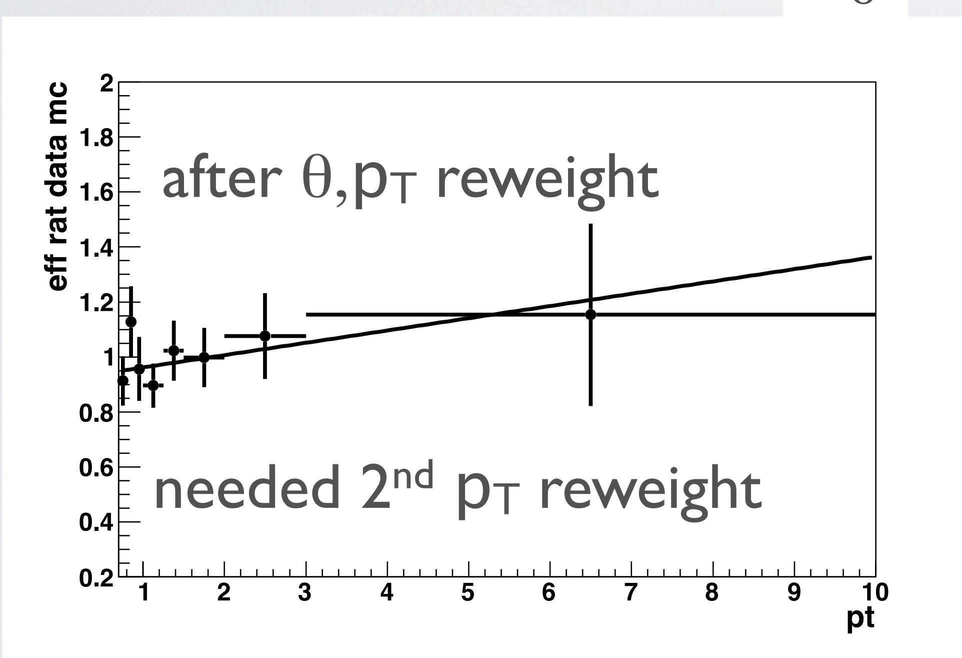


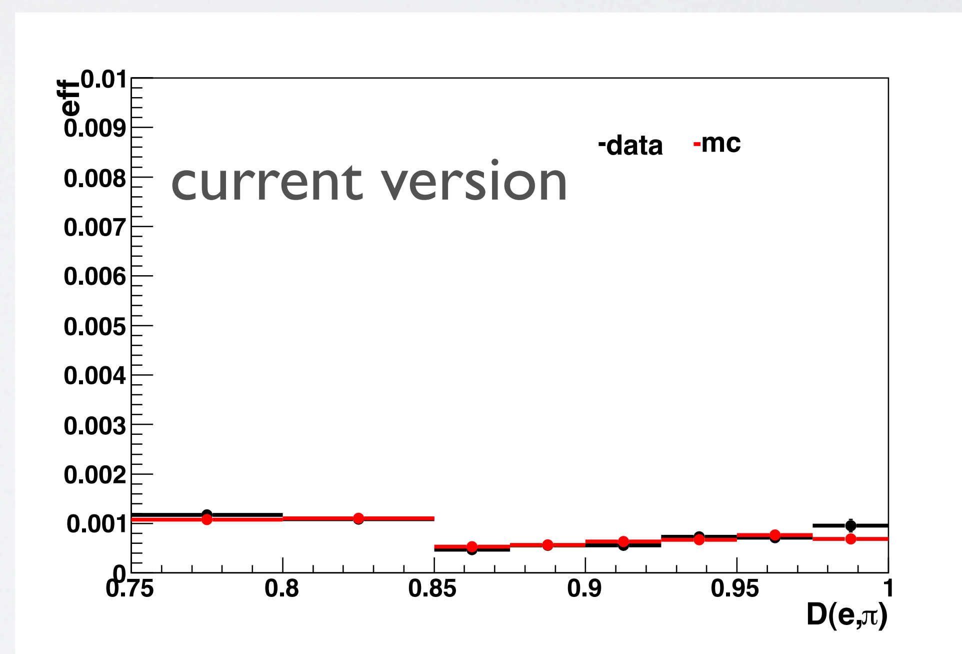


DISCRIMINATOR RESPONSE - PIONS FROM K^0





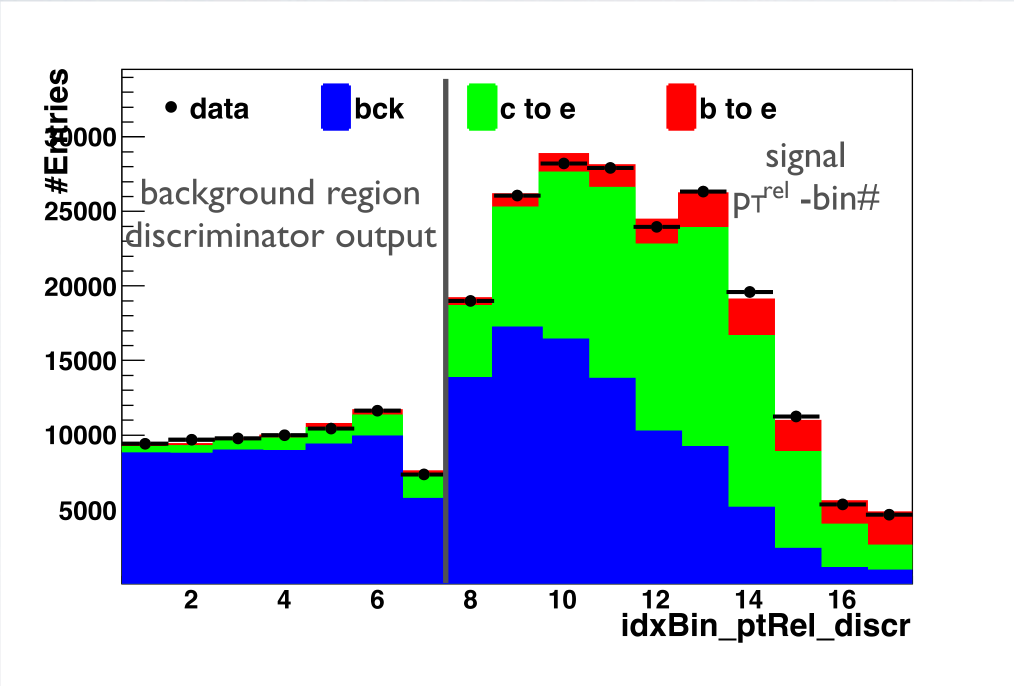




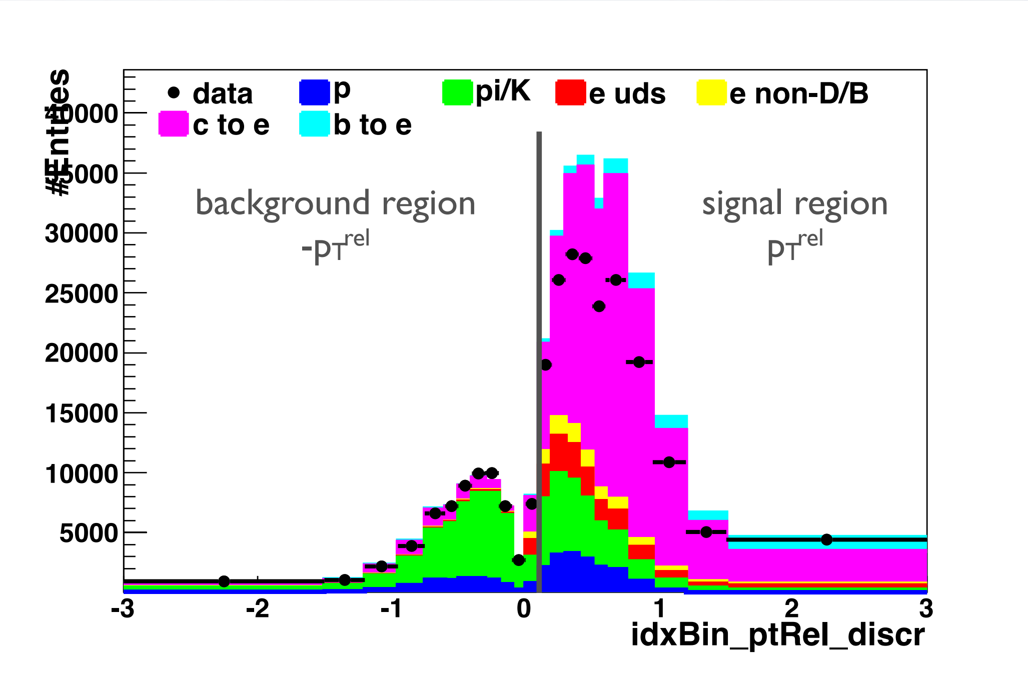
Better agreement between data and MC - no correlations with θ,p_T

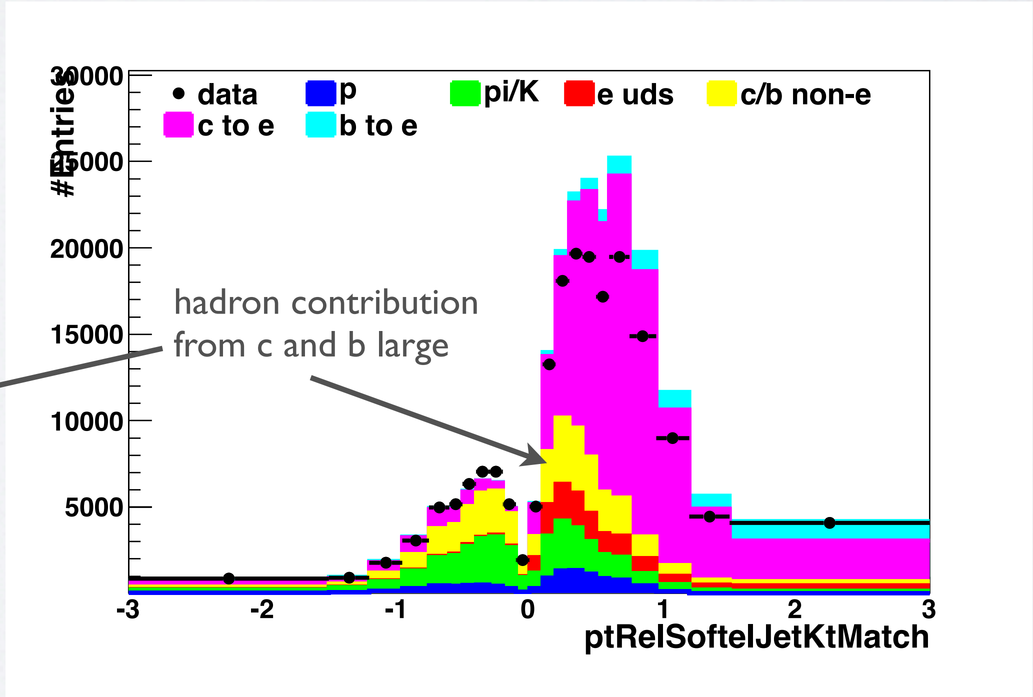
FRACTION FITTING

old style (fit result)



new style (not fitted)





old fractions:

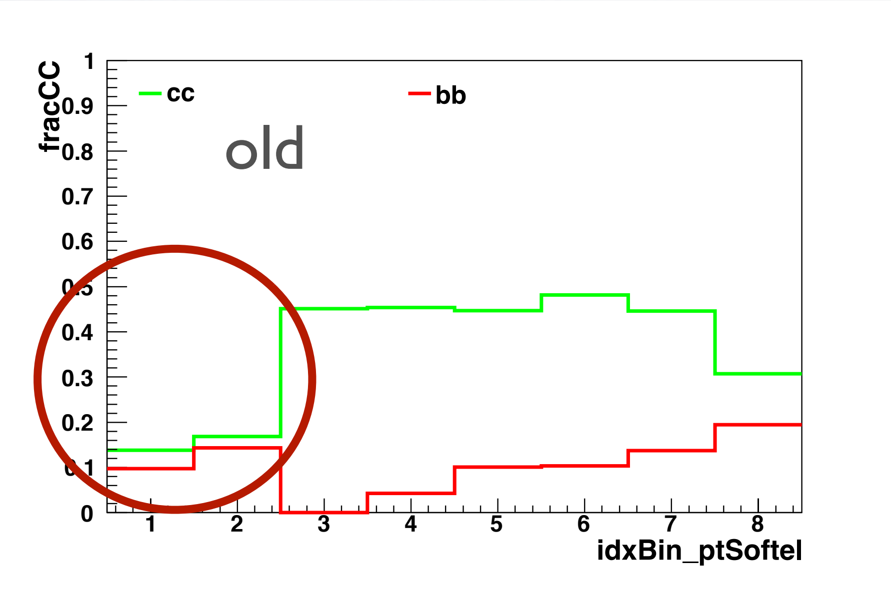
hadrons+conv-γ/c→e/b→e

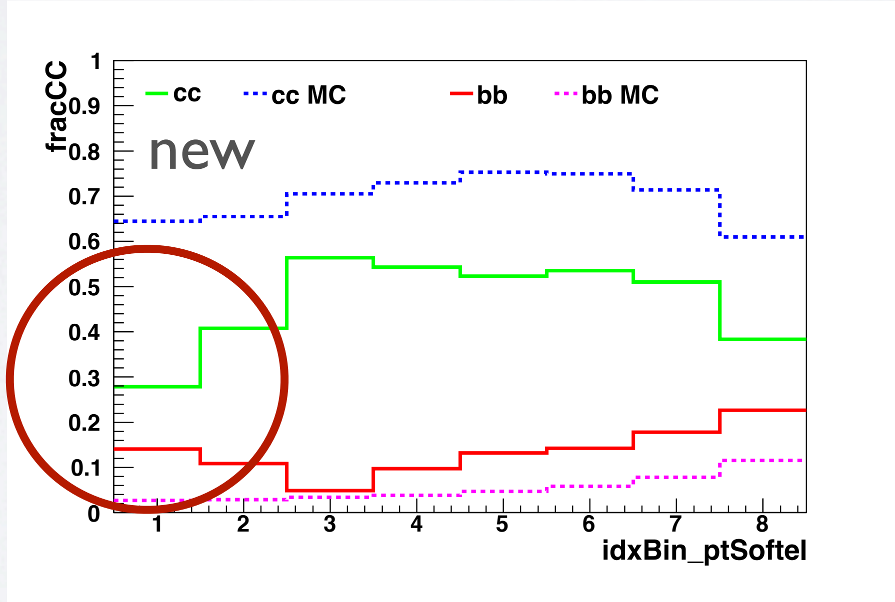
new fractions:

uds,c and b

FURTHER CHANGES

- Implementation of H1BoostedJets corrected
  (p_T^{Jet}-cut was not correctly defined - recovered losses)
- currently p_T^{rel} calculated including the electron candidate
  (improves stability of fits)
- fragmentation reweight also applied to hadrons
  (would also need reweight of decay spectrum - but how???)
- signal calculation after fraction fit corrected
  (was very background region dependent - now very stable except at low p_t)

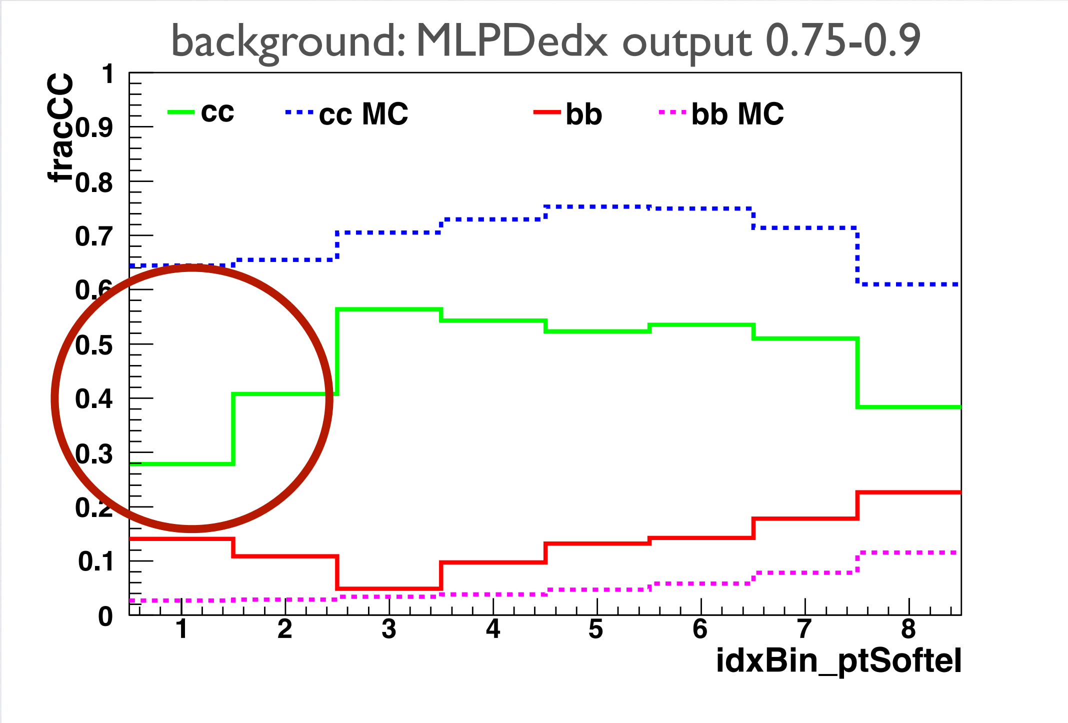


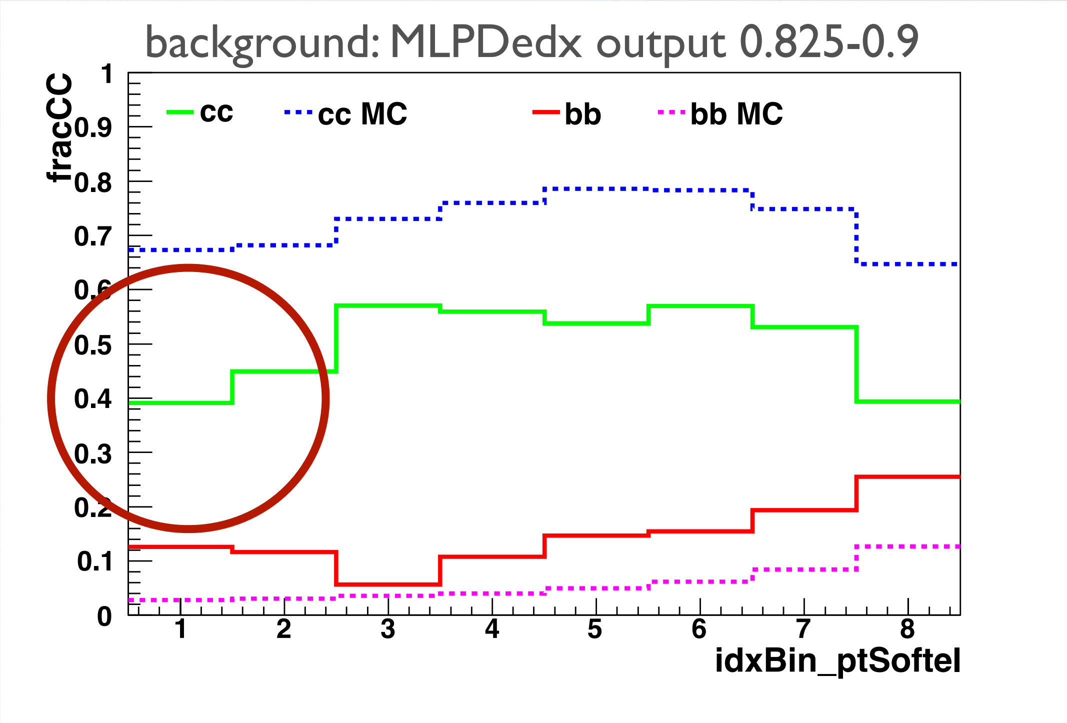


Somewhat better behaviour at small p_t

STILL QUITE SOME OPEN PROBLEMS

- Many changes implemented including some fixes
- Signal extraction not stable yet: still some dependance on background region (mainly in p_t)



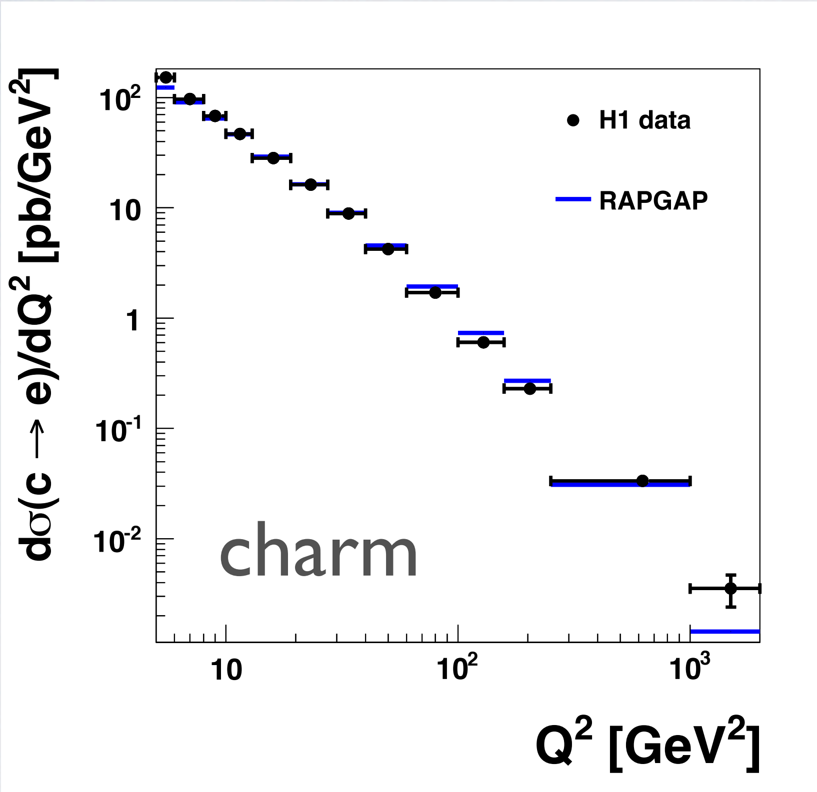


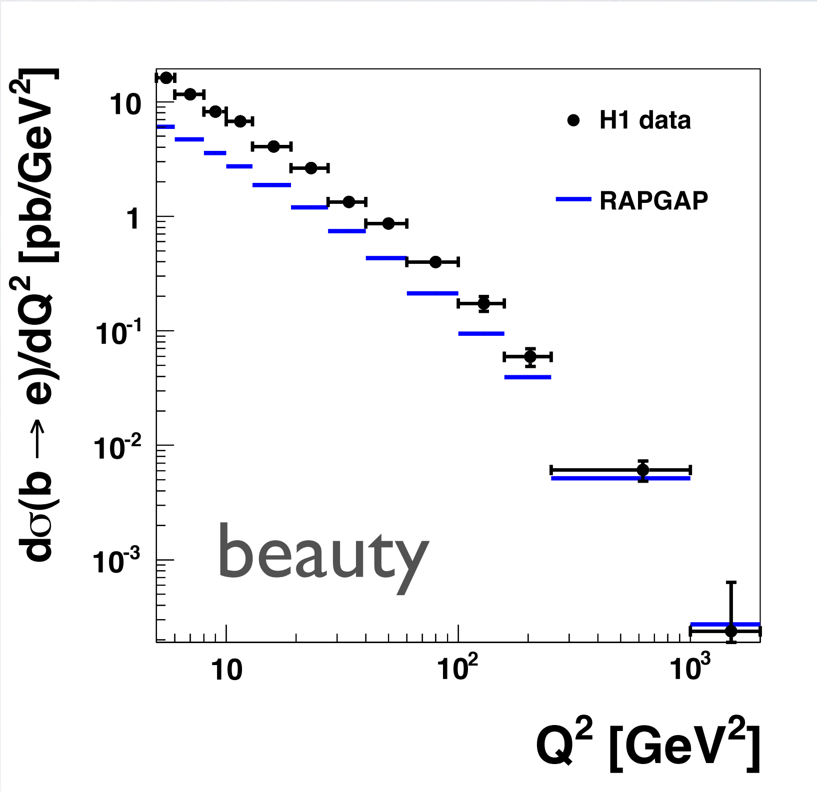
- Still problems with efficiency calculation: fitted fractions and observed event rates smaller than predicted but calculated charm cross section larger than in MC

CONCLUSIONS

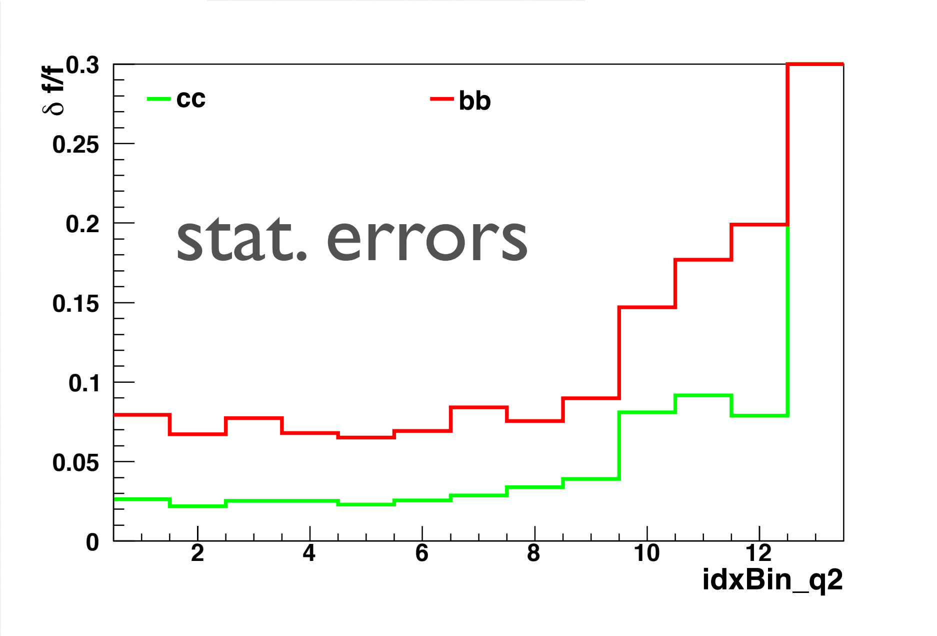
- Analysis of c/b→electrons continues
- Some improvements implemented solving some issues
- Behaviour of proton-electron discriminator has to be checked
- Efficiency issue has to be understood
- Inclusion of additional observables c/b discriminating power will be studied

JUST AN APPETISER





current stage with all the open issues discussed



This is how it could look like