# Study of the Bose-Einstein Correlations in pp interactions at 0.9 and 7 TeV

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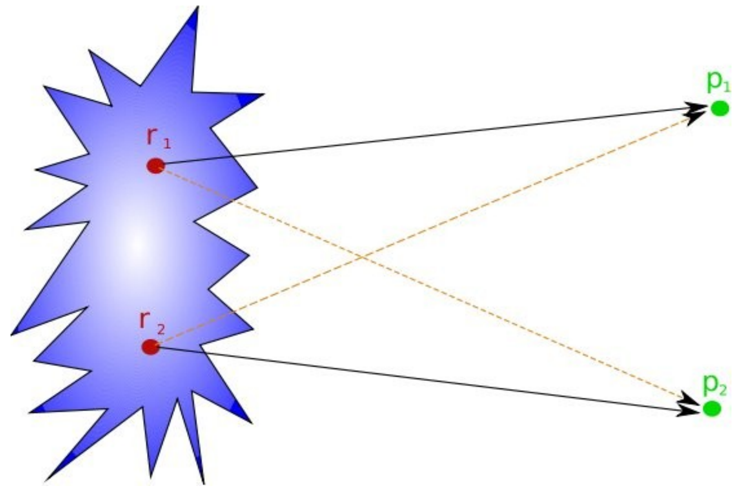
# Theoretical background

**BEC effect correspond to an enhancement in two identical boson correlation function when the two particles are near in momentum space**

space-time characteristics of hadronization region

$$C_2(q) = \frac{P(p_1, p_2)}{P(p_1)P(p_2)}$$

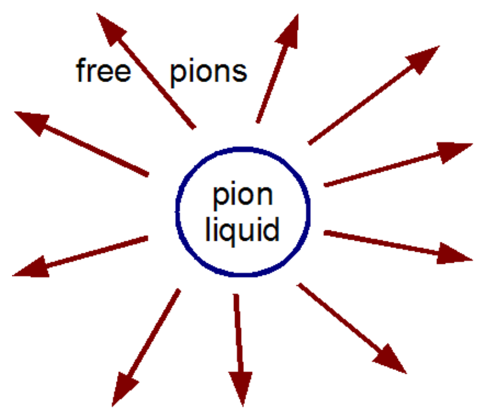



**Plane wave approach (incoherent sum):**
**For Gaussian source emission probability**

$$C_2(Q) = 1 + \lambda e^{-Q^2 R^2}$$

$R$ **is the source radius**

$\lambda$ **is the *incoherence factor (0,1)* introduced empirically**




$Q^2 = -q^2 = (p_1 - p_2)^2$ **= the four momentum difference**

**Quantum optical approach (taken from optics):**

- **based on squeezed coherent states**
- **leads to:** $C_2(Q) = 1 + 2p(1-p) e^{-R^2 Q^2} + p^2 e^{-2R^2 Q^2}$

$p$ **is the chaoticity: =0 ( =1) for purely coherent (chaotic) sources**

# Other approaches

**Quantum Field Approach (Q.field theory at finite temperature):**

$$C_2(Q)=\xi(N)\cdot[1+\frac{2\alpha}{(1+\alpha)^2}\sqrt{\tilde{\Omega}(Q)}+\frac{1}{(1+\alpha)^2}\tilde{\Omega}(Q)]\cdot F(Q,\Delta x)$$

$$\frac{\langle N(N-1)\rangle}{\langle N\rangle^2}$$

$$F(Q,\Delta x)=\frac{f(Q,\Delta x)}{f(p_1)\cdot f(p_2)}=1+r_f Q+\ldots$$

$$\tilde{\Omega}(Q)=\Omega(Q)\cdot\gamma(\nu)$$

$$\Omega(Q)=\exp([-(q_0^2R_0^2+q_L^2R_L^2+q_T^2R_T^2)])$$

$C_2$ **taken as a function of** $Q^2=-(p_1-p_2)^2\rightarrow$ **dependence on** $p_1+p_2$ **not considered !**

**Two-dimensional approach to BEC correlations!**

# C2 function: experimental approach

- **For each track pair we reconstruct the quantity** $Q=\sqrt{(E_1-E_2)^2-(\vec{p}_1-\vec{p}_2)^2}$

**The Q++, Q--, Q+-,Q-+ are the quantities for pairs of the like/unlike sign particles.**

- **The C2 correlation function is a ratio of the like sign particle (track) pairs Q distributions' sum (signal distributions N(Q)(with BEC)) and the unlike sign particle (track) pairs Q distribution (reference distribution N*ref*(Q) (without BEC,but contain all other correlations.))**

**We construct the C2 correlation function**

++ and -- track pair combinations

$$C_2(Q)=\frac{N(Q)}{N^{ref}(Q)}$$

It is a problem!!! ←

+- track pair combinations

N(Q) ≡ two particles Q distribution
- identical particles used

**Reference function – two basic possibilities:**

**- non-identical track pairs taken from the same event ( N+-(Q) ) .**

**- Event mixing reference function: the same particle type track pairs created from different events ( $N_{EM}$++ --(Q) )**

**- Opposite hemisphere technique (inversion of the 2nd track direction)**

# Parametrization functions

**We used 6 fitting parametrization functions:**

**C2_1** $C_{2-1}=C_0(1+\lambda e^{-R^2Q^2})(1+Q\varepsilon)$

**C2_2** $C_{2-2}=C_0(1+\lambda e^{-RQ})(1+Q\varepsilon)$

**C2_3** $C_{2-3}=C_0(1+2p(1-p)e^{-R^2Q^2}+p^2e^{-2R^2Q^2})(1+Q\varepsilon)$

**C2_4** $C_{2-4}=C_0(1+2p(1-p)e^{-RQ}+p^2e^{-2RQ})(1+Q\varepsilon)$

**C2_5** (Kozlov fitting function)

$$C_{2-5}=\chi(N)(1+2\frac{\alpha}{(1+\alpha)^2}e^{\frac{-R^2Q^2}{2}}+\frac{1}{(1+\alpha)^2}e^{-R^2Q^2})$$

**C2_6** (Kozlov fitting function)

$$C_{2-6}=\chi(N)(1+2\frac{\alpha}{(1+\alpha)^2}e^{\frac{-R^2Q^2}{2}}+\frac{1}{(1+\alpha)^2}e^{-R^2Q^2})(1+Qr_f)$$

# Coulomb correction*

The measured N(Q) distribution for the like or unlike signed particle (track) pairs in presence of the Coulomb interaction is given by:

$$N_{meas}(Q) = G(Q)\,N(Q)$$

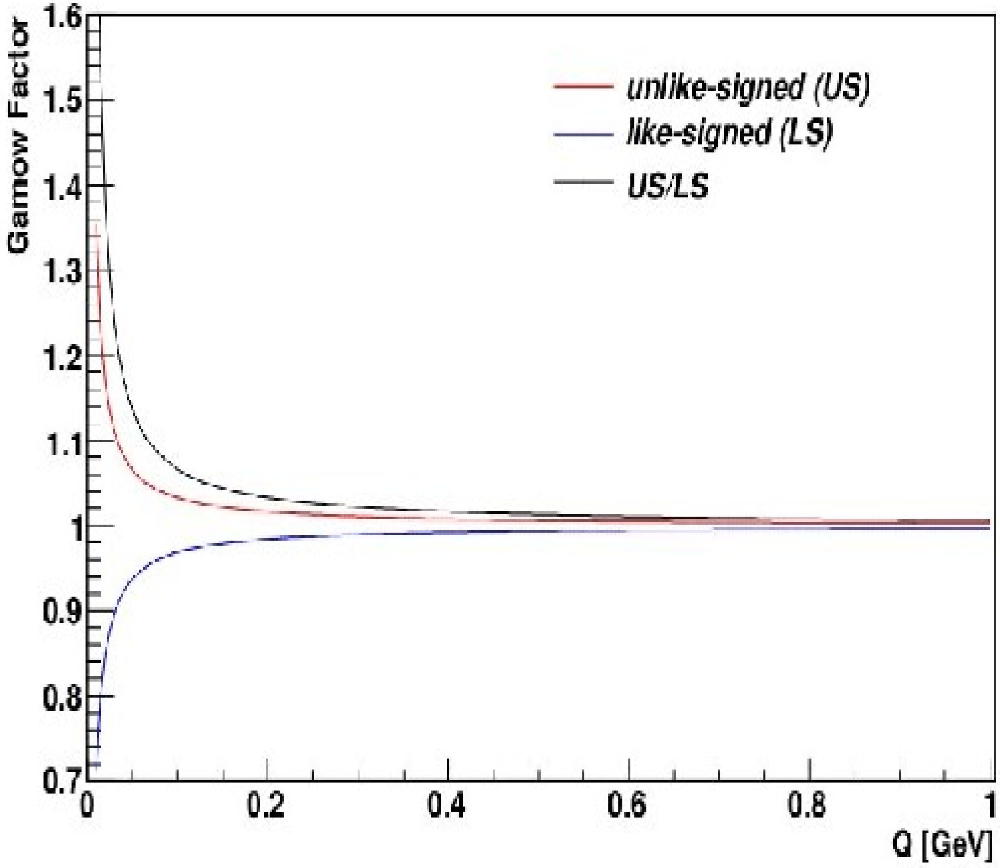
where N*meas*(Q) is the measured distribution, N(Q) is the distribution free of Coulomb correlations.

Gamow penetration G(Q) factor

$$G(Q) = \frac{2\pi\eta}{e^{2\pi\eta} - 1}$$

Sommerfeld parameter η

$$\eta = \frac{\pm\alpha_m}{|Q|}$$



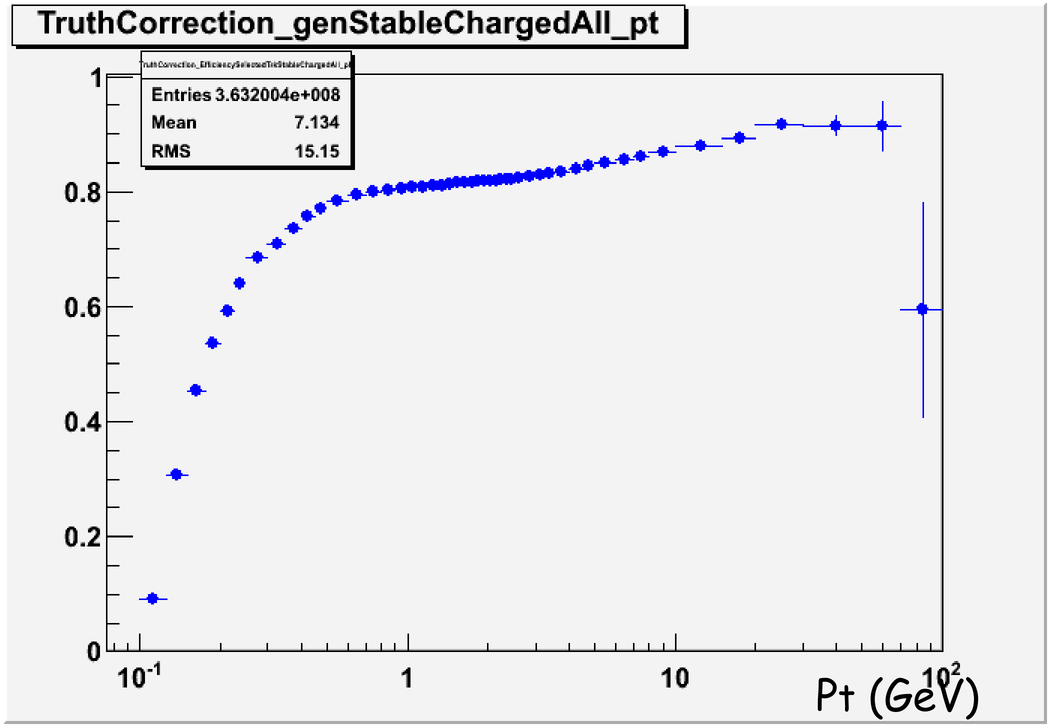



* 1 S.Pratt, PRD33, p72(1986)

# Efficiency correction

**Corrections on some efficiencies (functions of η and pt):**

* «reconstruction track efficiency»
* «trigger efficiency»
* «vertex reconstruction efficiency»




# Correction Data on MC:

$$C_2^{Corr} = \frac{C_2^{DATA}(Q)}{C_2^{MC}(Q)}$$

# Data samples

**Official MinBias D3PD samples for Experimental data and MC are used**

**900 GeV data samples:**
- **Experimental data samples:**
  **Number of selected events = 357,523**
- **MC data sample: (non-diffractive)**
  **Number of selected events = 975,742**

**7 TeV data samples:**
- **Experimental data samples:**
  **Number of selected events = about 10 millions**
- **MC data sample: (non-diffractive)**
  **Number of selected events = 14 millions**

**7 TeV Data sample with the high multiplicity trigger**
- **Experimental data samples:**
  **Number of selected events = 13,985**

# Event/ track selections (MinBias 2.0 analysis)

**Trigger:**

* L1_MBTS_1 | L1_MBTS_2 | L1_MBTS_1_1 trigger
* good run/lumiblocks

**Vertex Selection:**

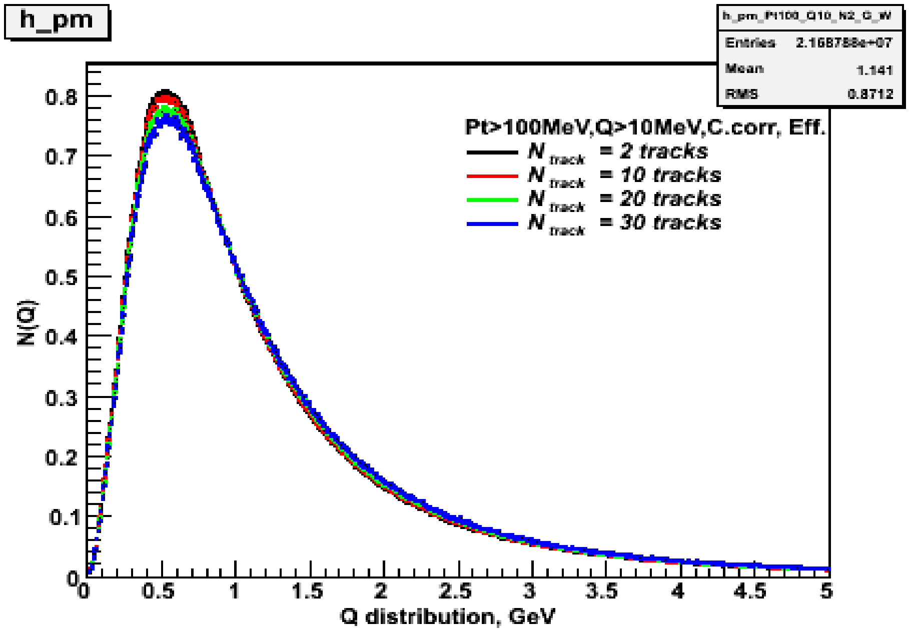
* Pile-up Removal cut
* >=1 vertex
* >=2 "selected" track (as vertex requires 2 tracks)

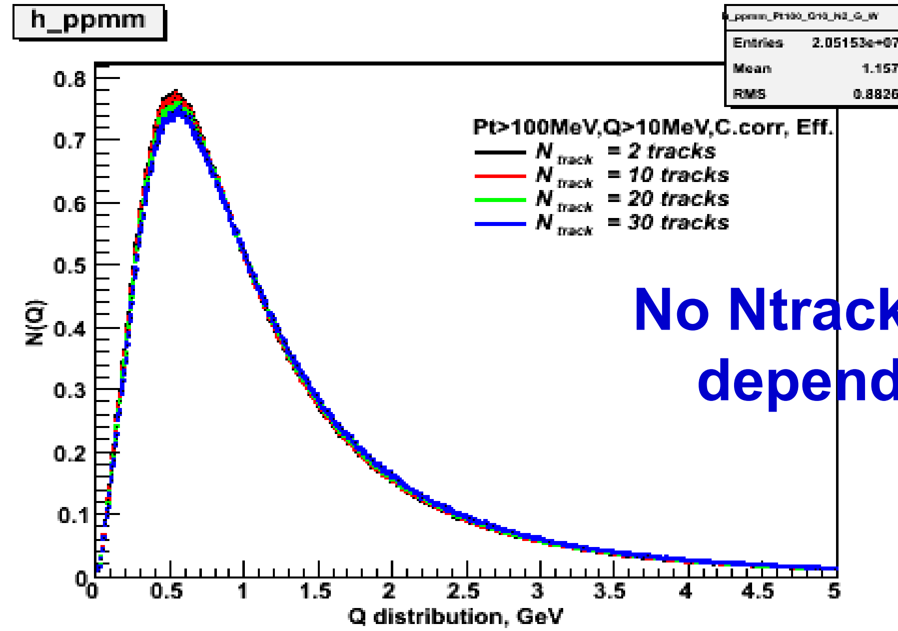
**Track Selection:**

* Pt > 100. MeV
* abs(eta) < 2.5
* |d0| < 1.5 mm
* |z0 sin(theta)| < 1.5 mm
* b-layer hit if one expected
* >=1 pixel hit
* >= 2,4,6 SCT hits for pt > 100,200,300 MeV
* Chi2 prob > 0.01 for pt > 10 GeV (to remove the mis-measured tracks).

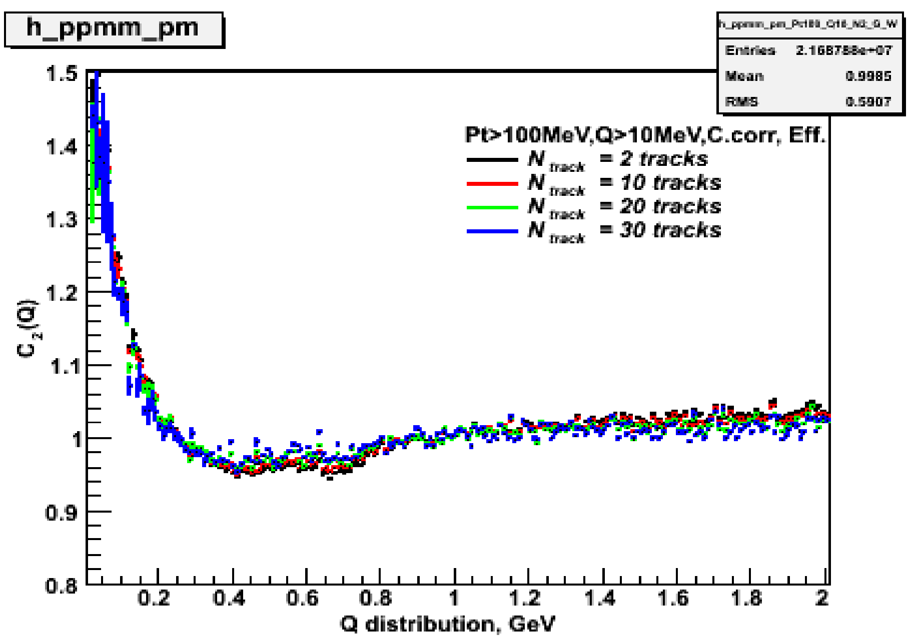
# 900 GeV: Q distributions, C2 functions, Ntracks Cuts

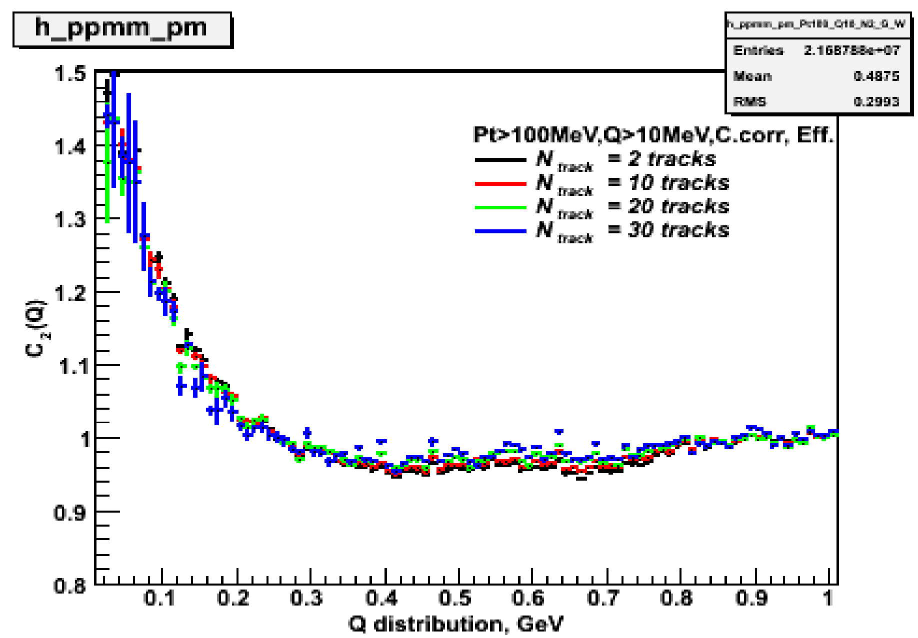
## Coul. & eff. corrections, Pt > 100 MeV, Q > 10 MeV



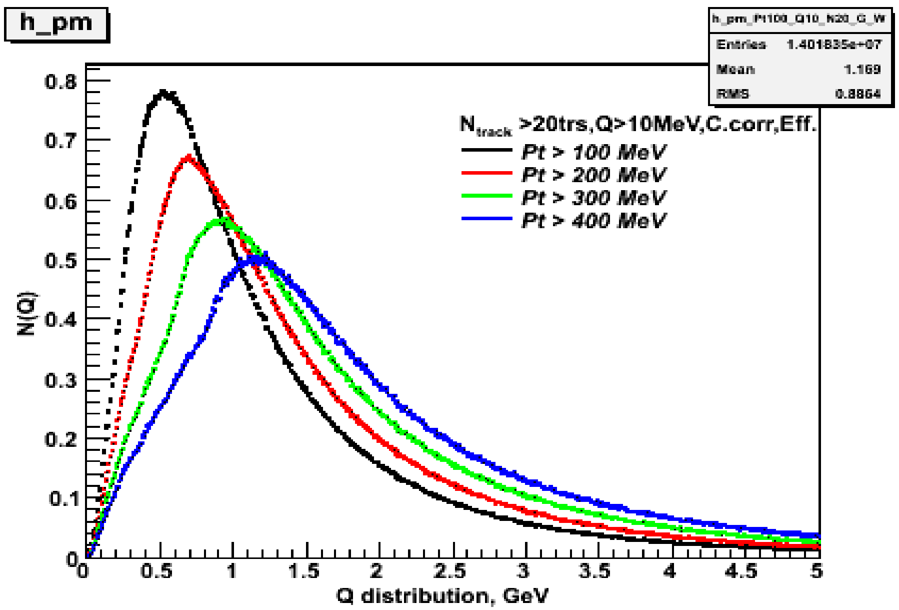

No Ntracks Cut's dependence

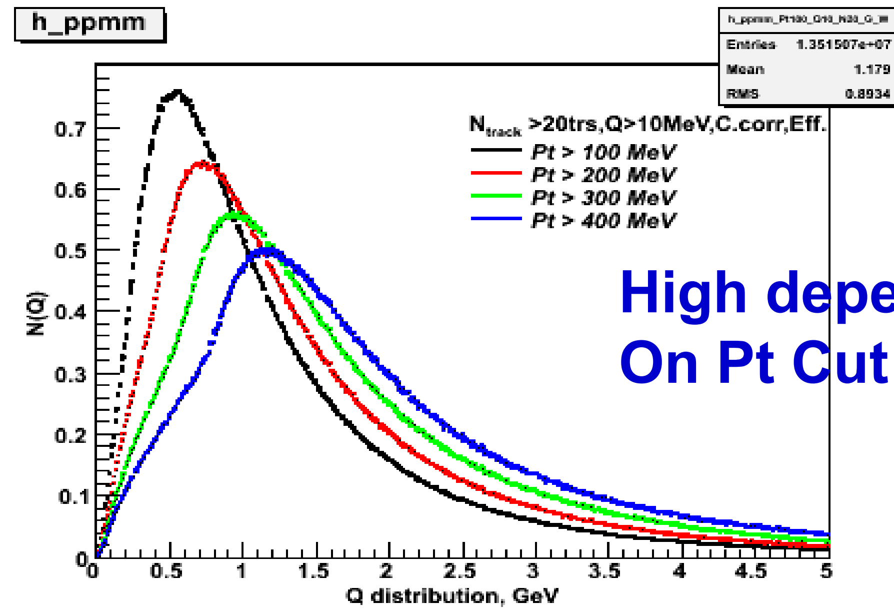


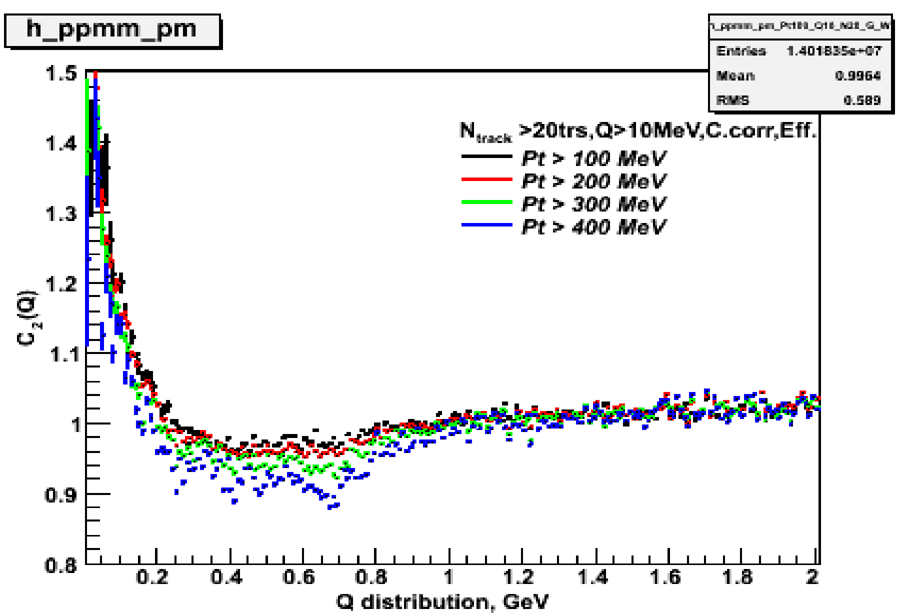
# 900 GeV: Q distributions, C2 functions, Pt Cuts

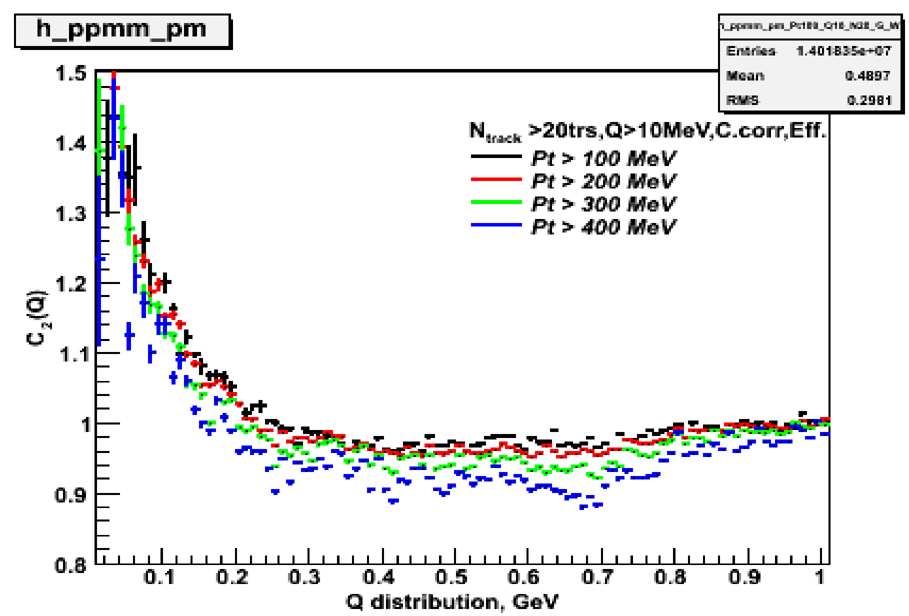
## Coul. & eff. corrections, Q > 10 MeV, Ntracks cut > 20 tracks




High dependence
On Pt Cut value

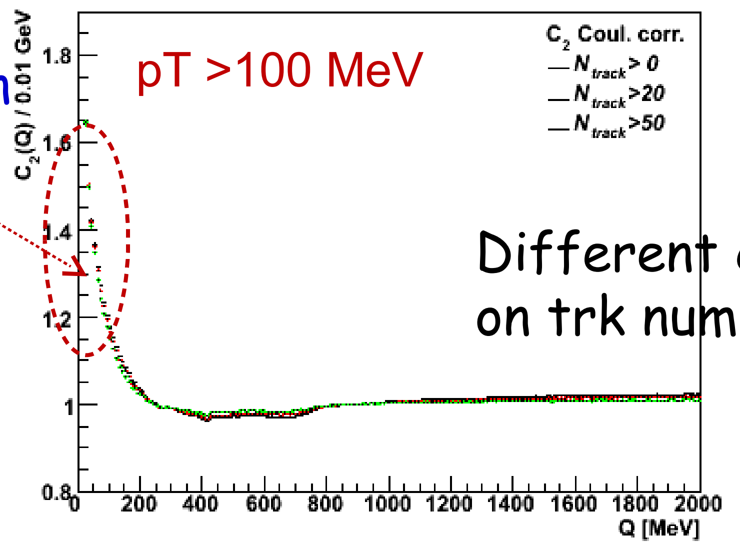


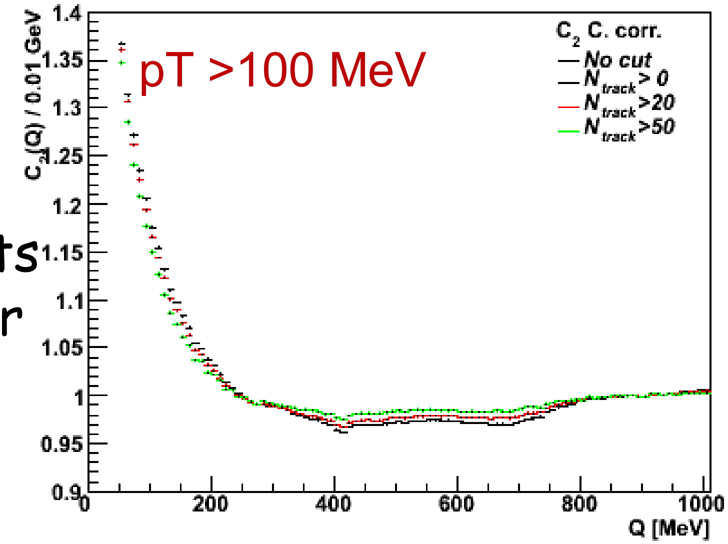
# 7 TeV: C2 functions, Pt & Ntracks Cuts

## Coul. & eff. corrections, Q > 10 MeV, Ntracks cut > 20 tracks

Coulomb correction
Diverge for Q ≈ 0

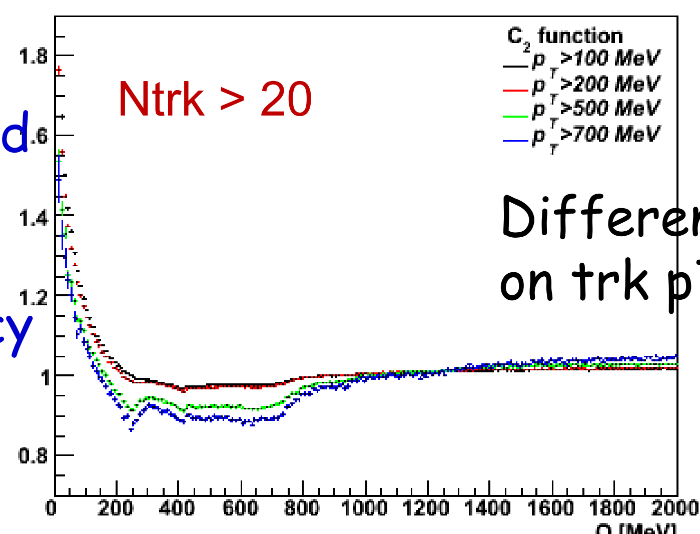



Different cuts on trk number

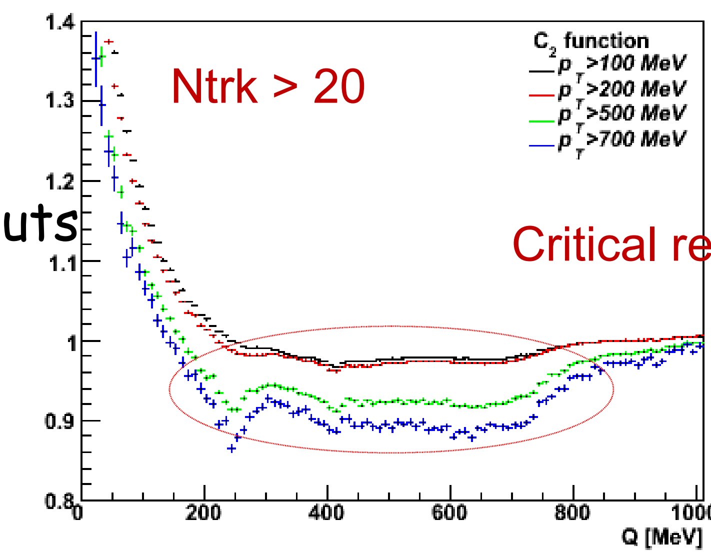



Critical region:
Resonances, jets ?
Was investigated

Trench less profound for low Pt cuts:
Use Pt-cut as low as possible => efficiency can be a problem




Different cuts on trk pT

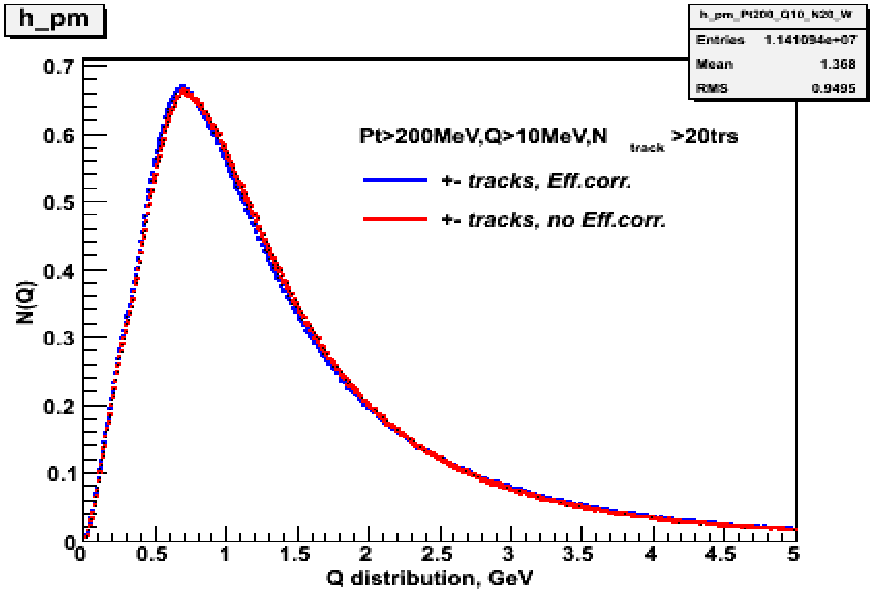


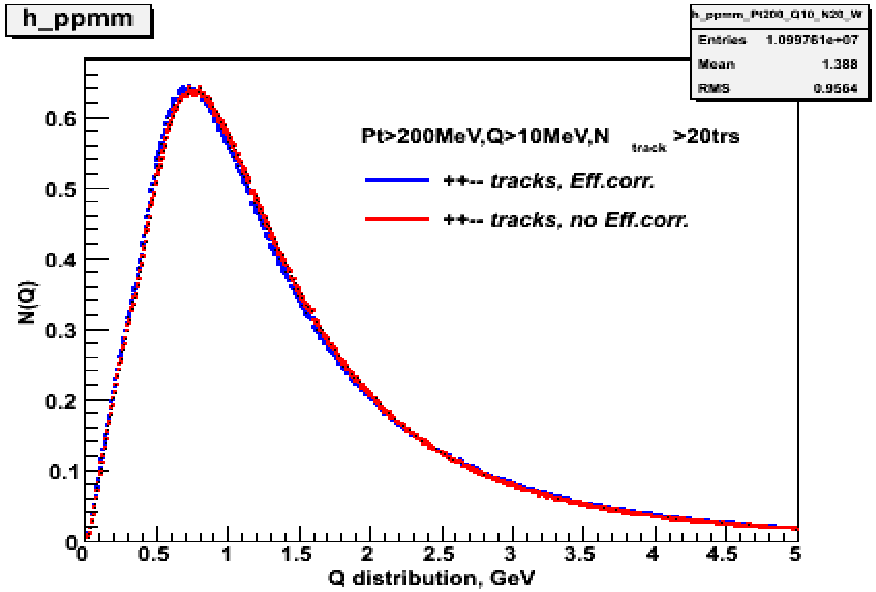

Critical region

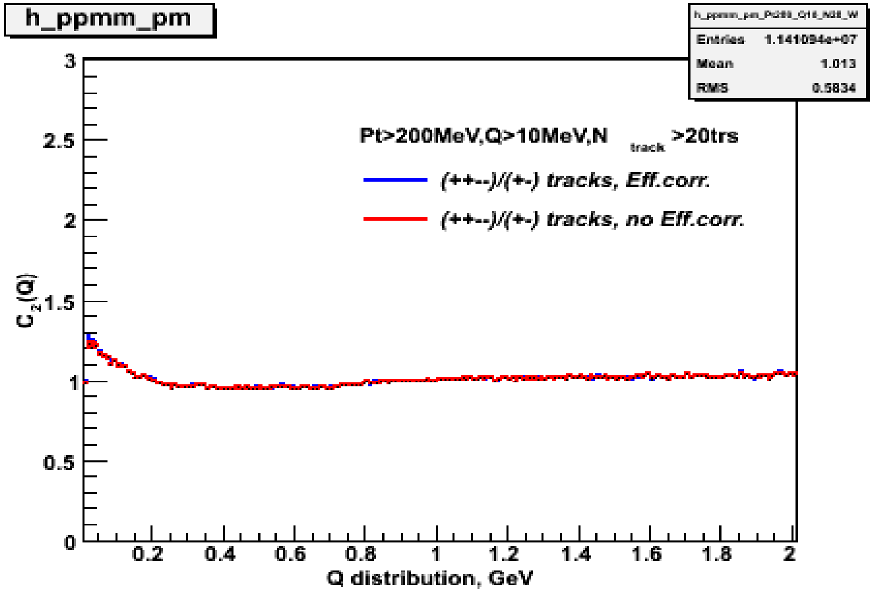
C2 shape depends on trk pT cut quit strong ly!

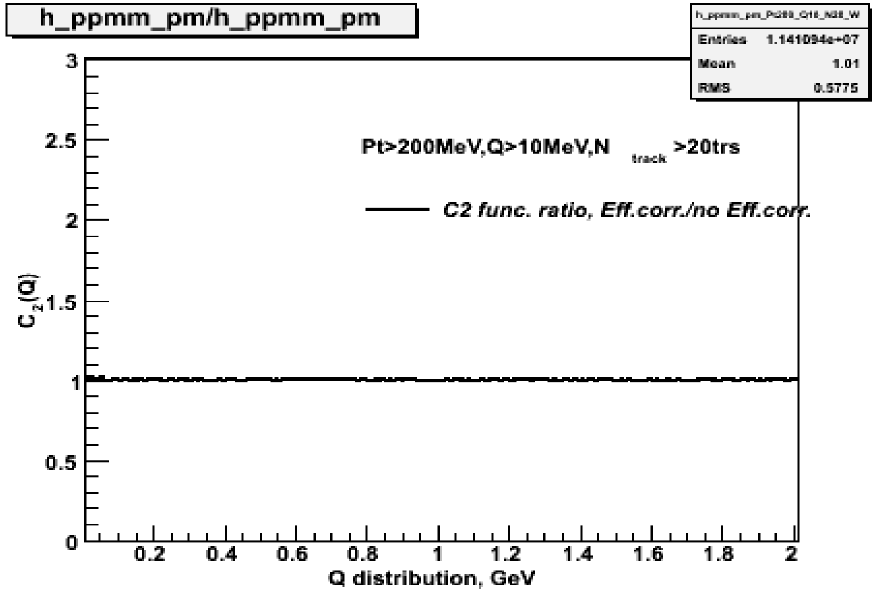
# 900 GeV :Q distributions, C2 functions

## With/without Tracks and Events correction efficiencies
## Pt> 200 MeV, Q > 10 MeV, Ntracks > 20 tracks



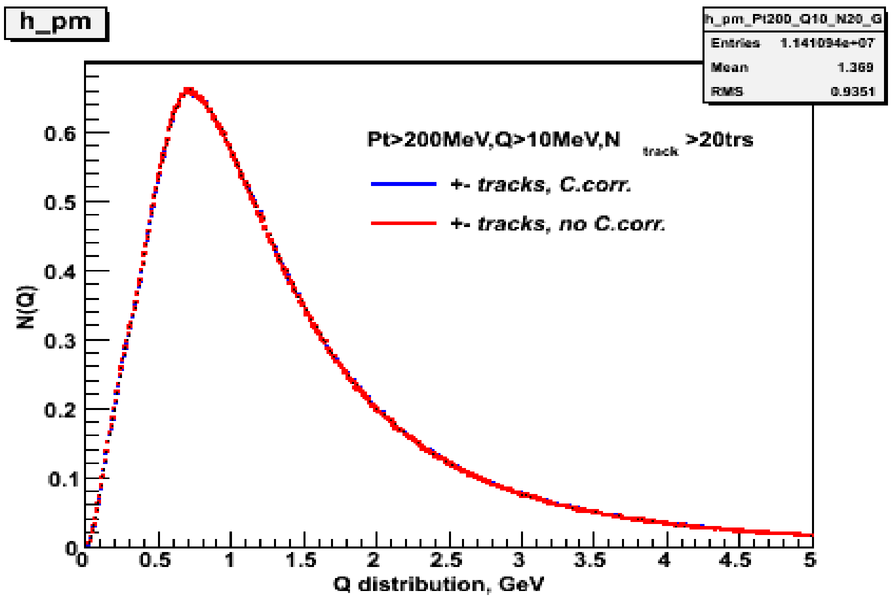



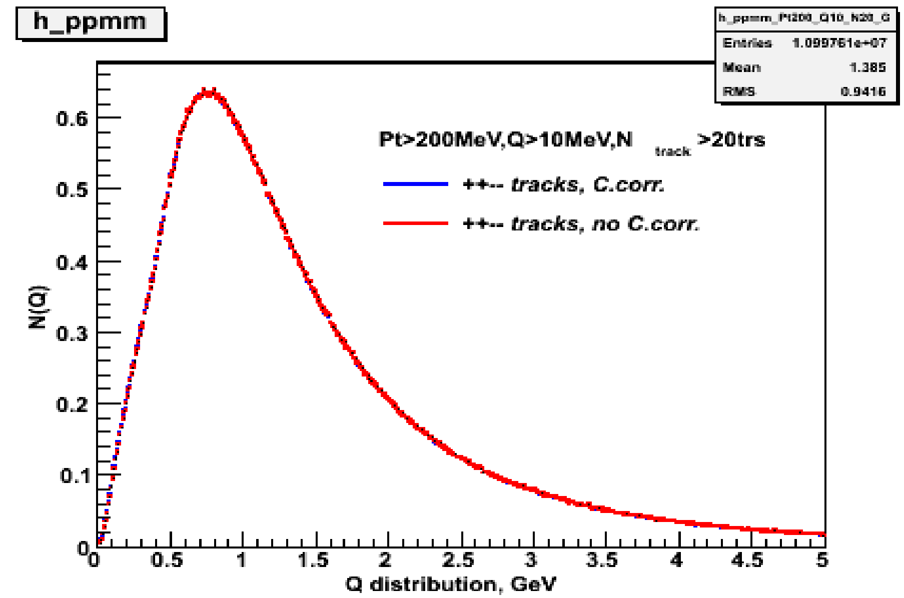



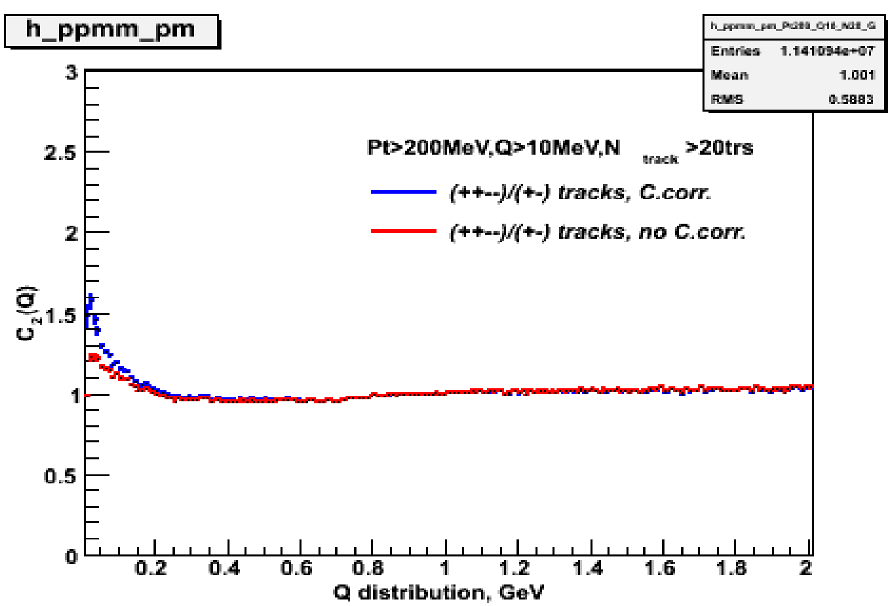
# 900 GeV: Q distributions, C2 functions

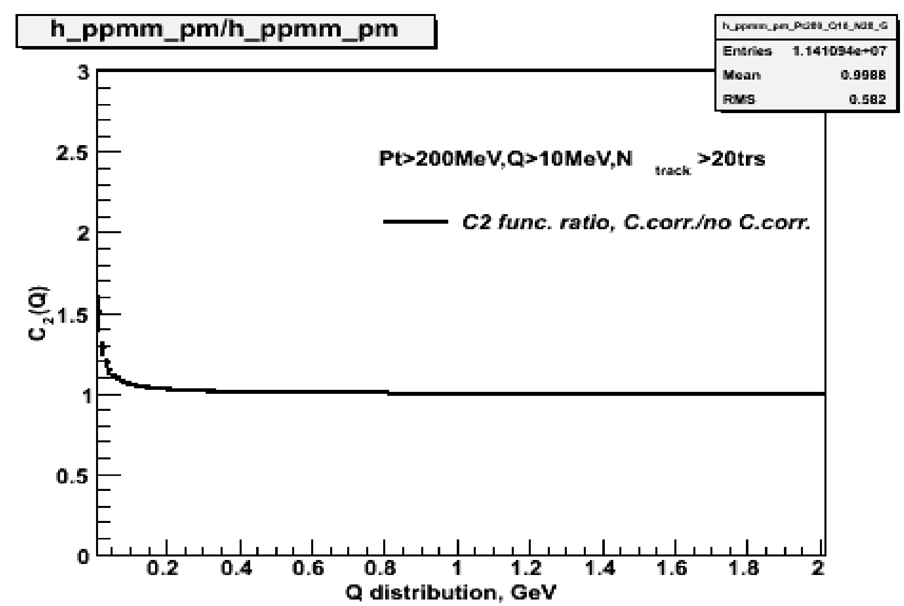
## With/ without Coulomb correction

## Pt> 200 MeV, Q > 10 MeV, Ntracks > 20 tracks



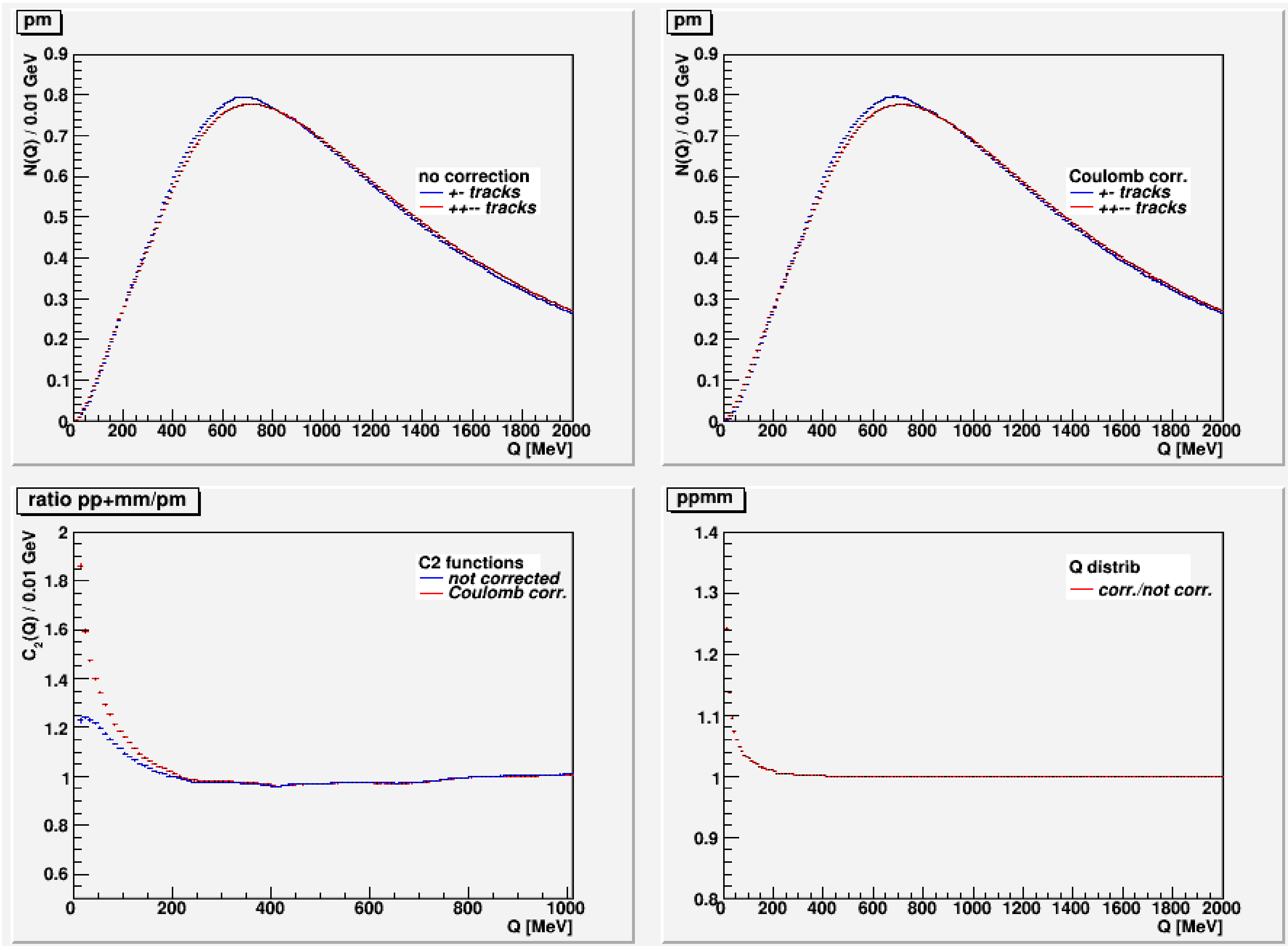



# 7 TeV: Q distributions, C2 functions

## With/ without Coulomb correction

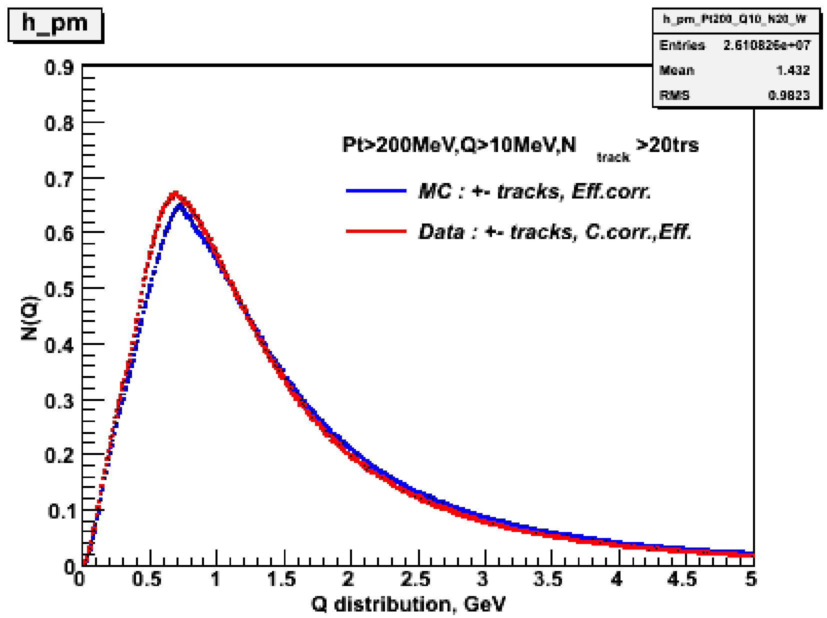
## Pt> 100 MeV, Q > 20 MeV, Ntracks > 20 tracks

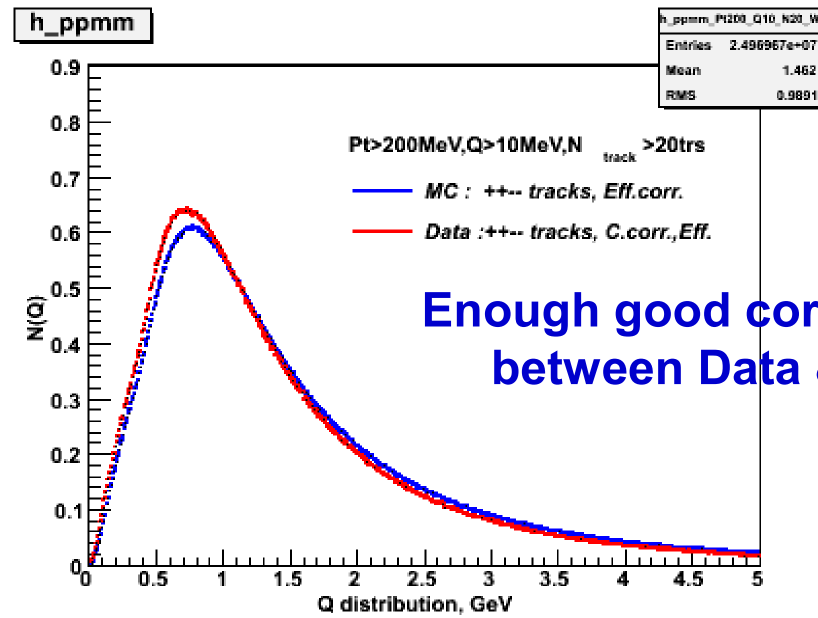


# 900 GeV: MC data & Collisions data:

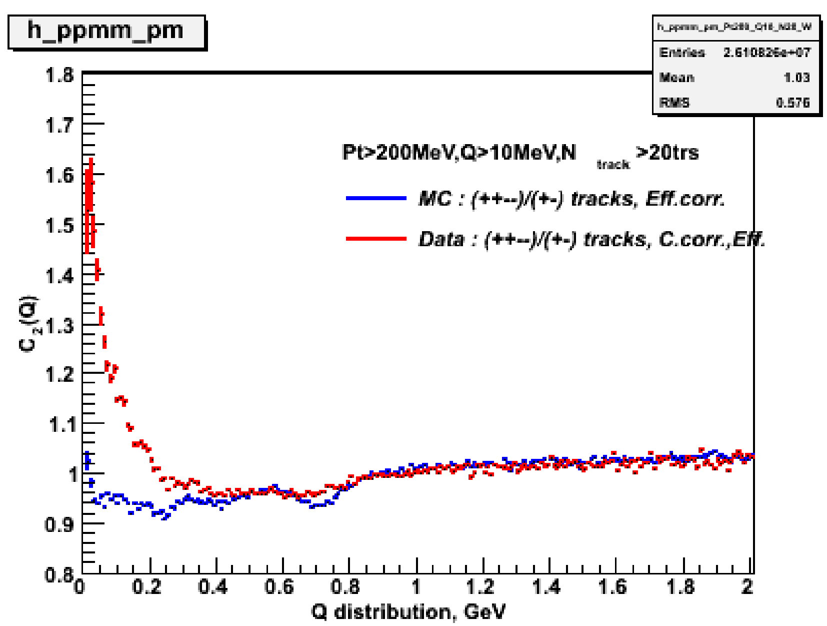
# Q distributions, C2 functions

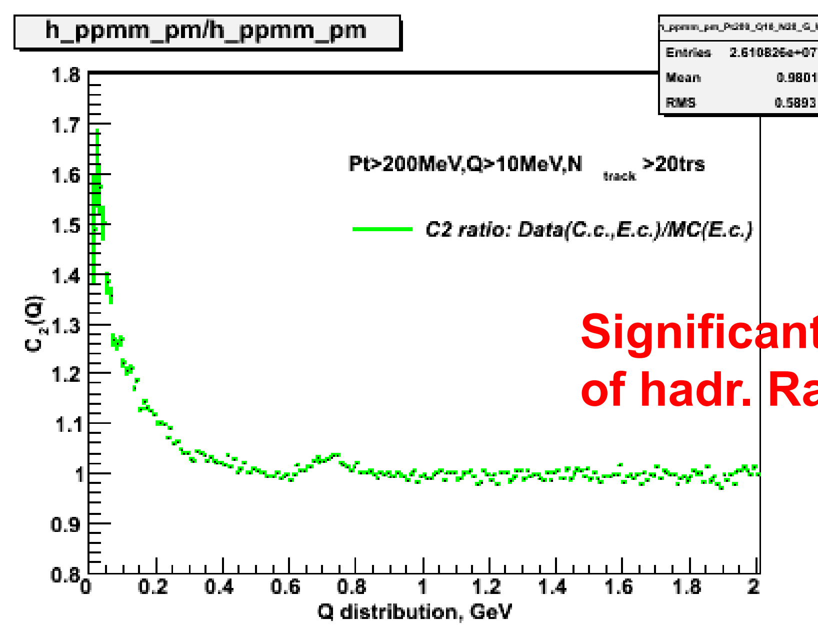
## Coul. & eff. corrs, Pt> 200 MeV, Q > 10 MeV, Ntracks > 20 tracks




Enough good correlation between Data & MC

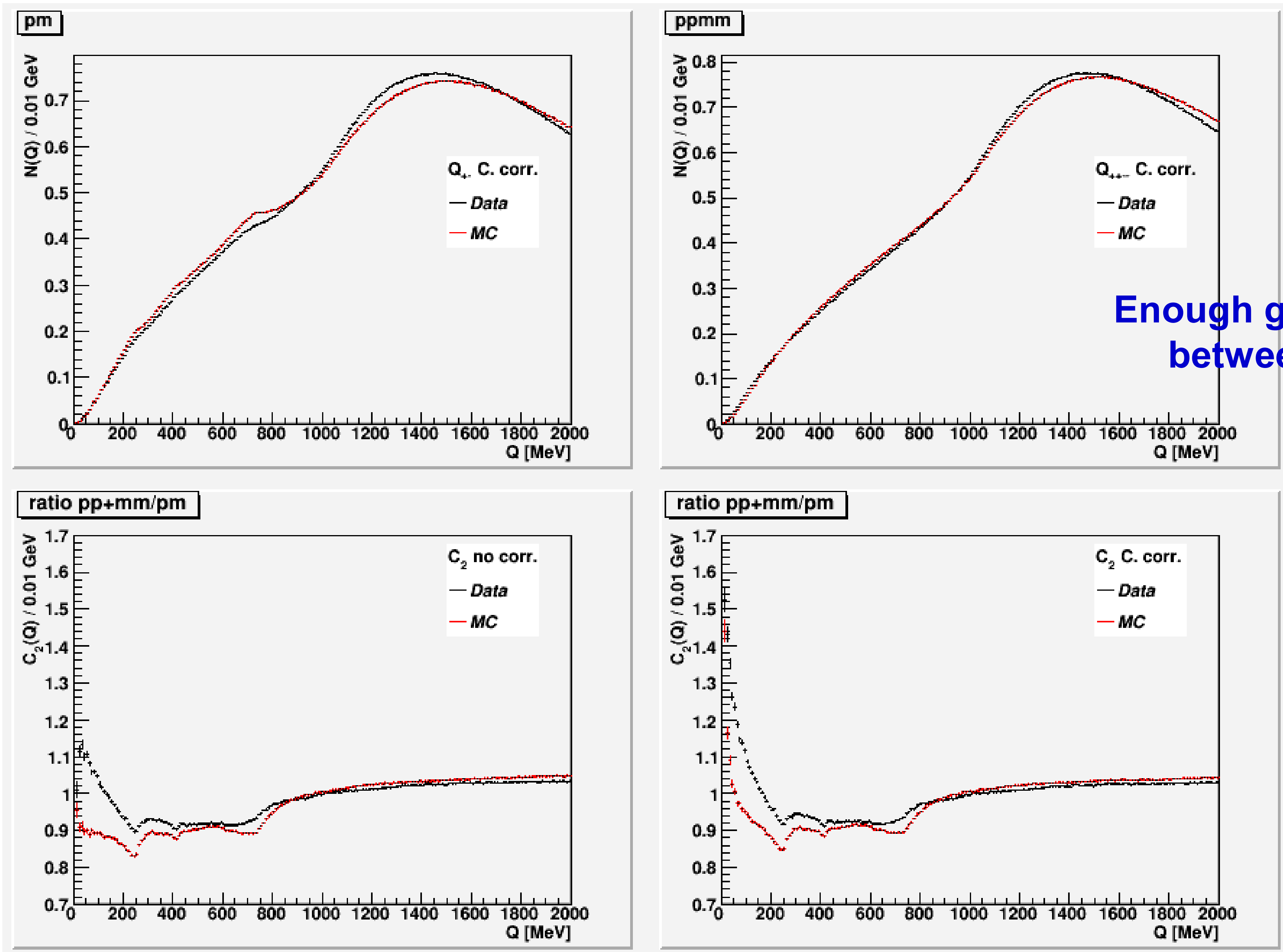



Significant change of hadr. Radius !

# 7 TeV: MC data & Collisions data:
# Q distributions, C2 functions

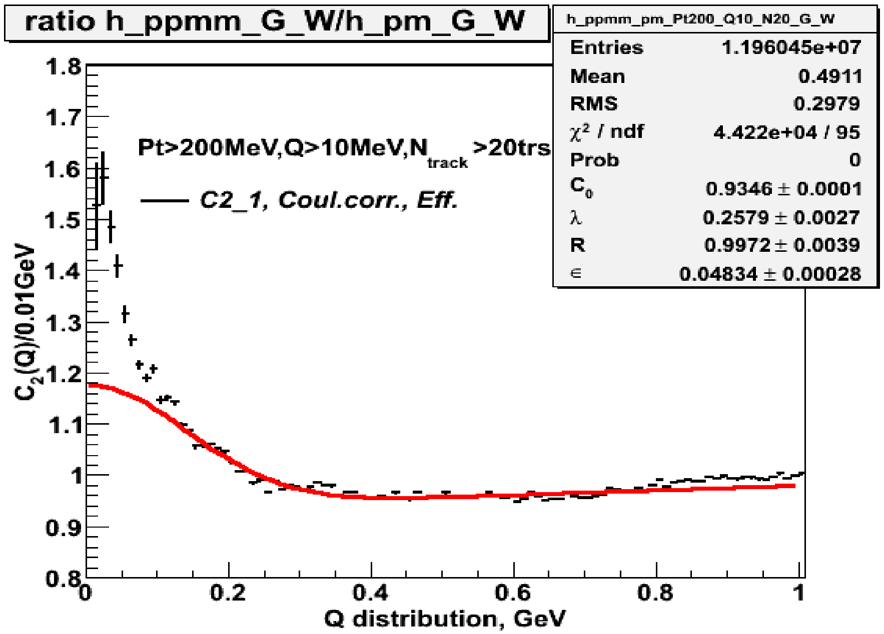
## Coul. & eff. corrs, Pt> 500 MeV, Q > 10 MeV, Ntracks > 20 tracks

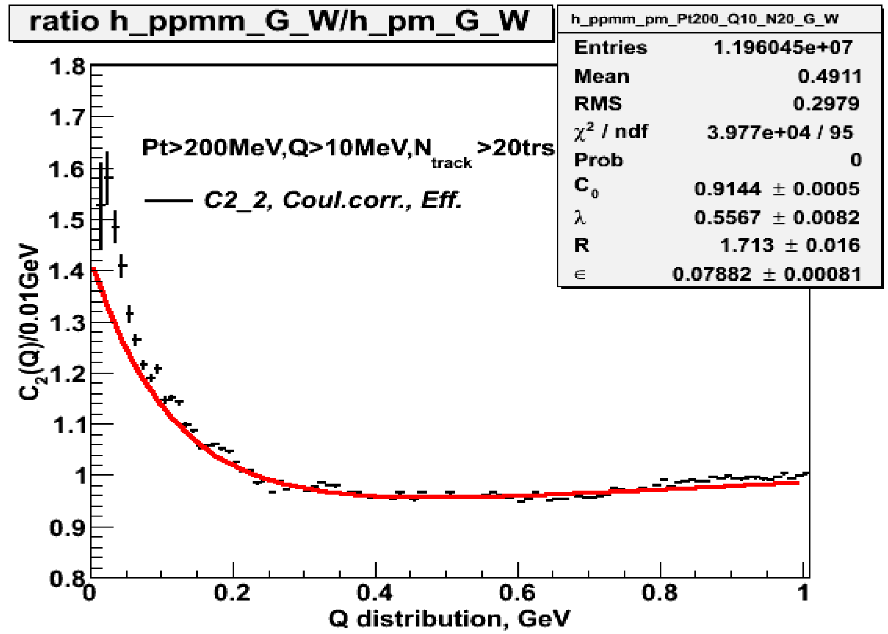


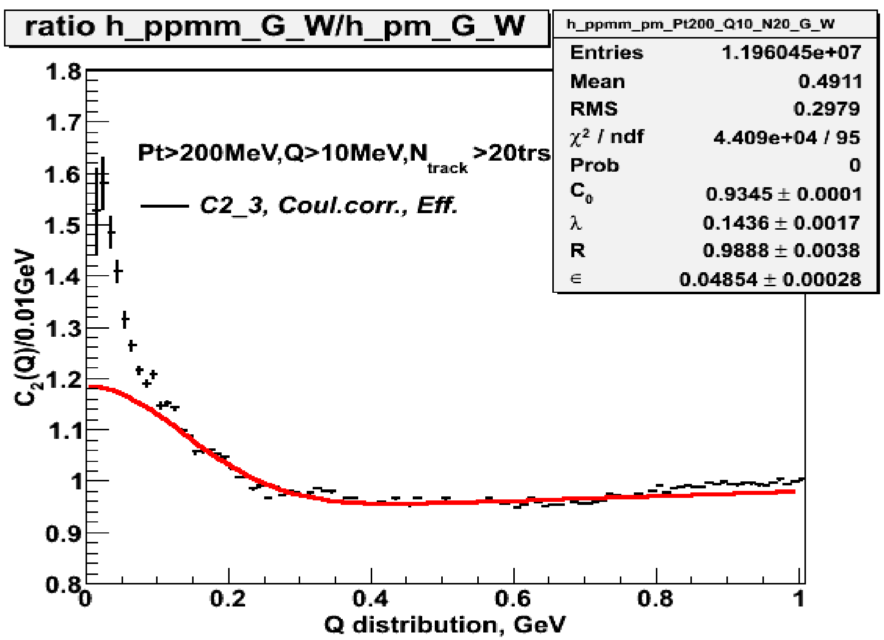

**Enough good correlation between Data & MC**

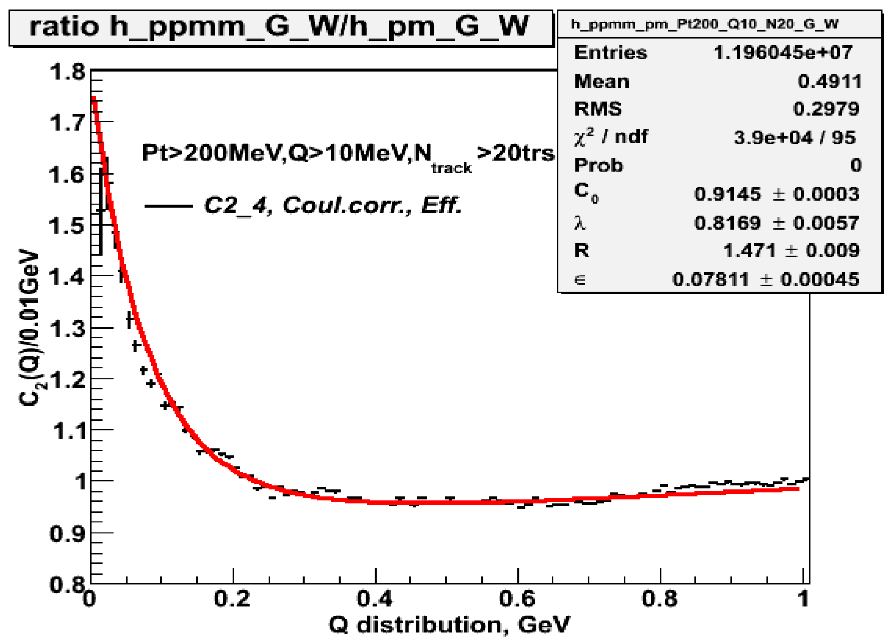
# 900 GeV : Collisions data : C2 function fitting

## Coul. & eff. corrections, Pt> 200 MeV, Q > 10 MeV, Ntracks > 20 tracks, full fitting interval



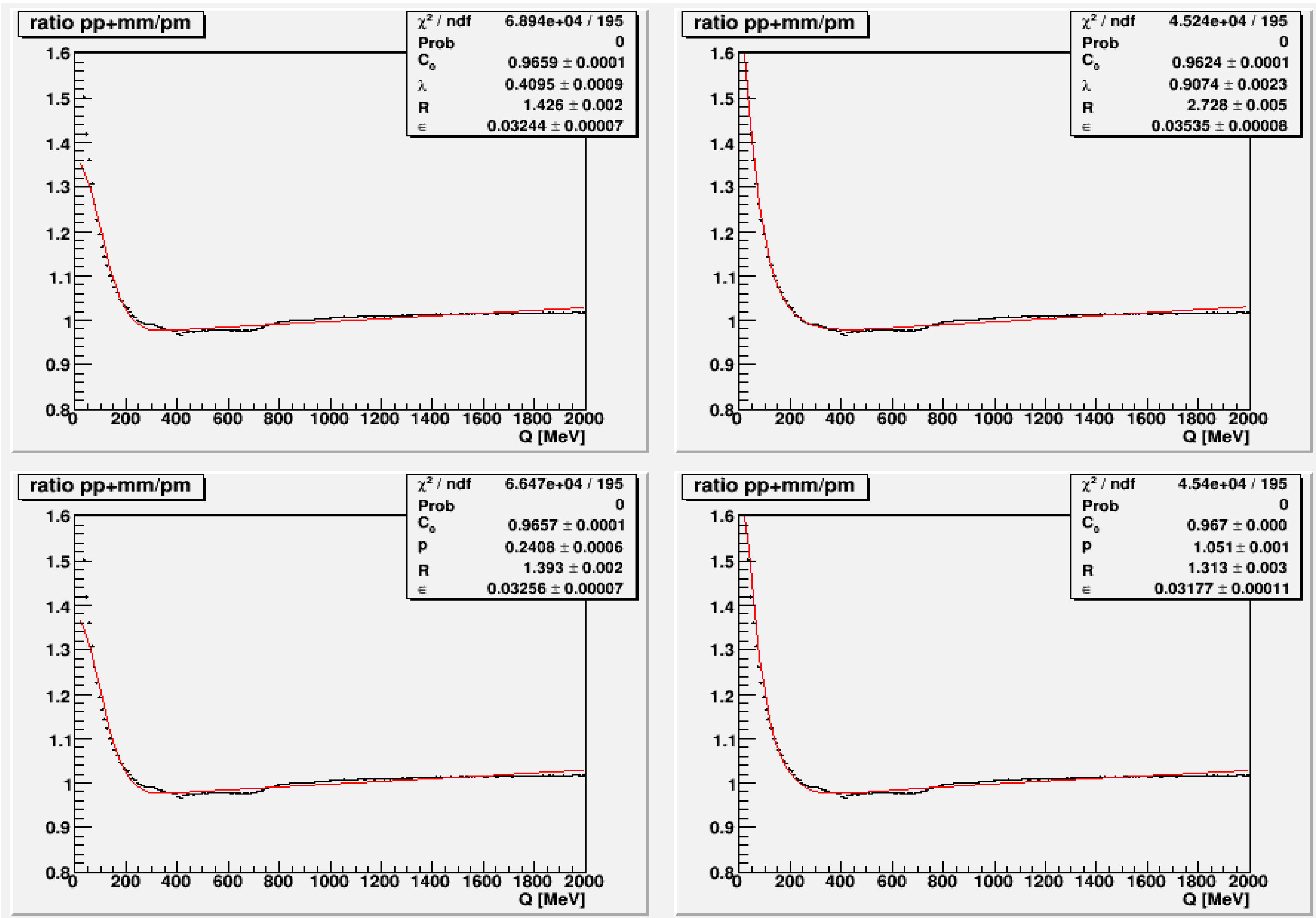



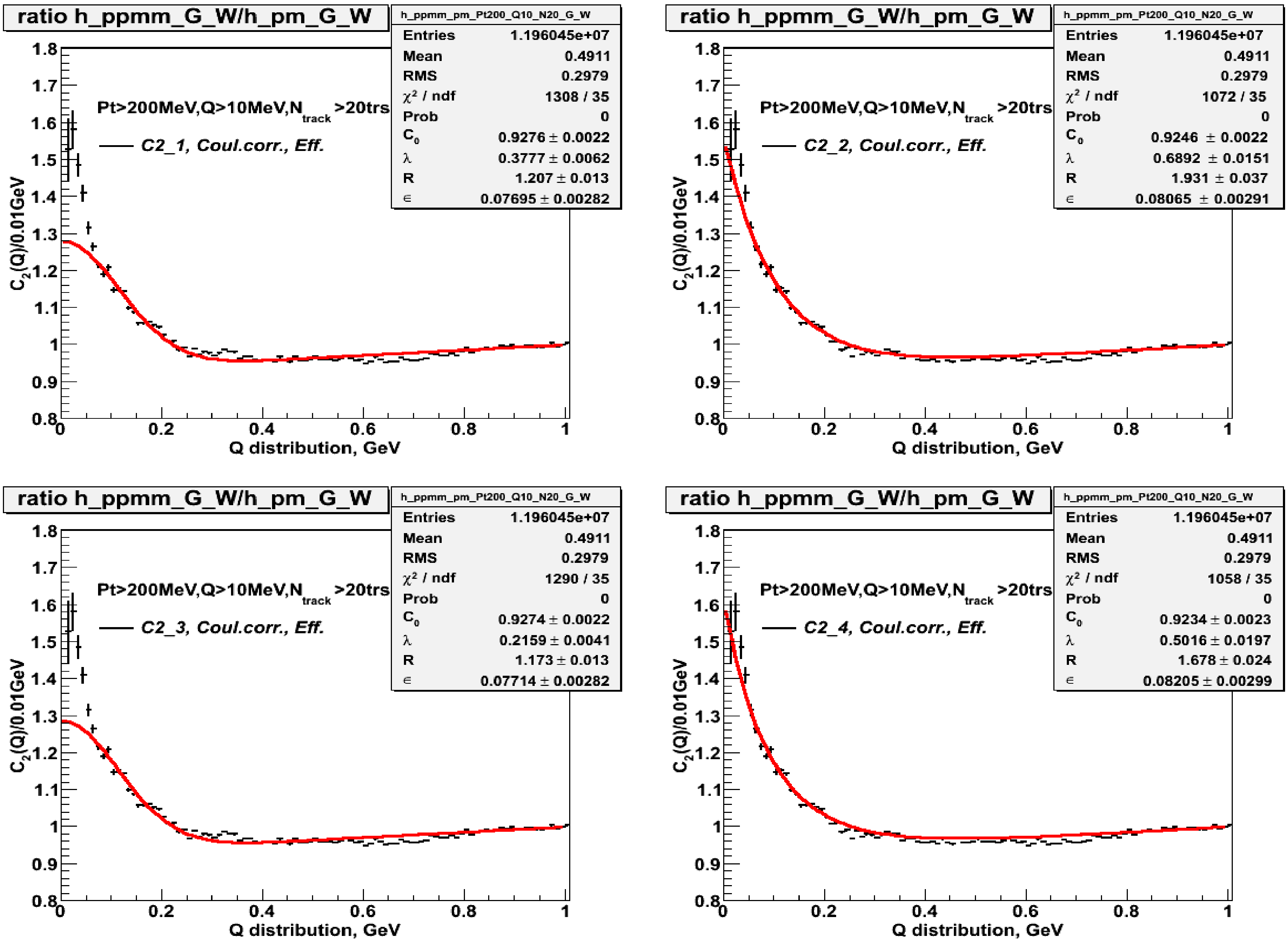
# 7 TeV : Collisions data : C2 function fitting

**Coul. & eff. corrections, Pt> 100 MeV, Q > 10 MeV, Ntracks > 20 tracks, full fitting interval**



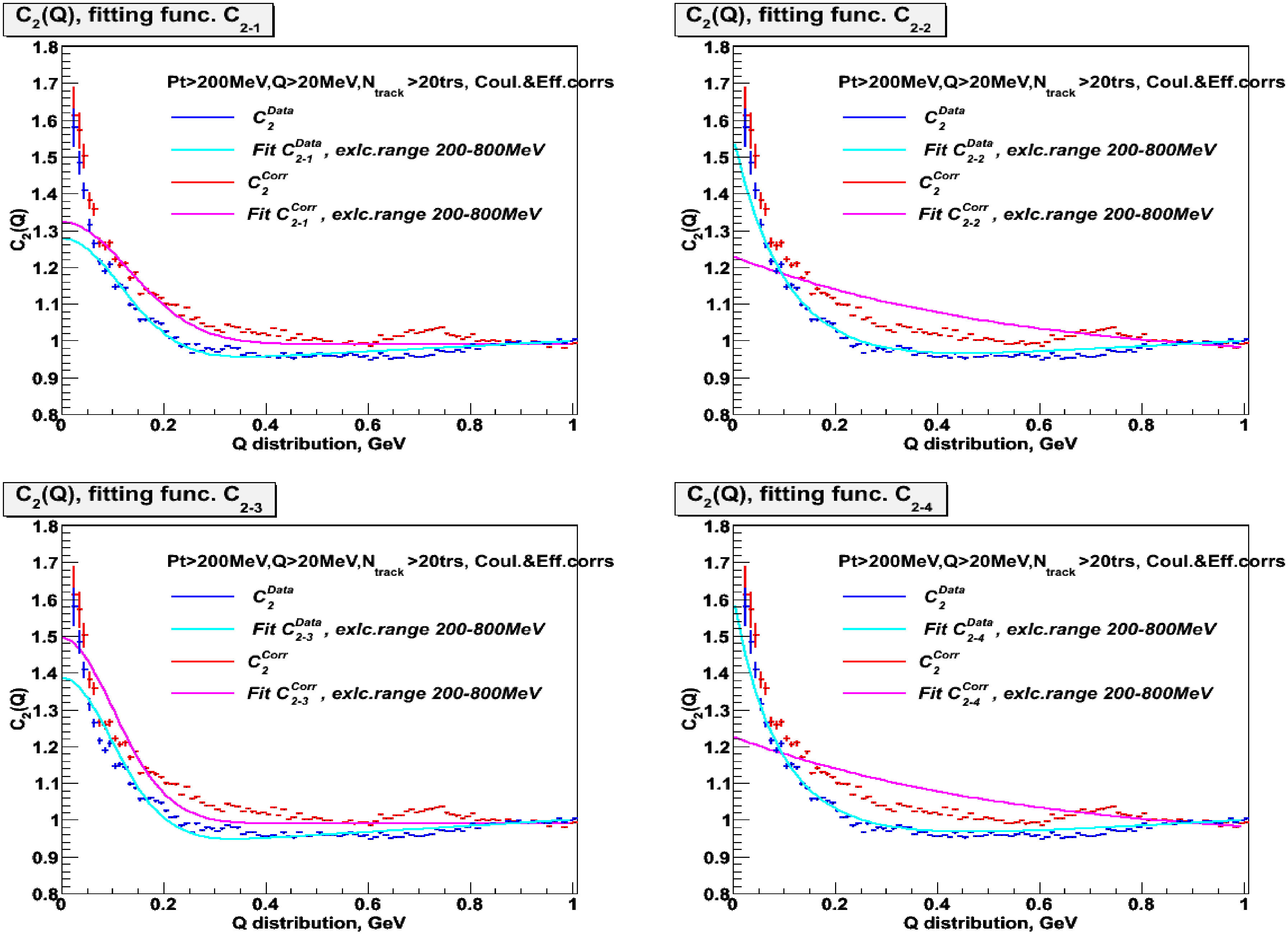
# 900 GeV : Collisions data :   C2 function fitting

## Coul. & eff. corrections, Pt> 200 MeV, Q > 10 MeV, Ntracks > 20 tracks, excluded region (200-800MeV)



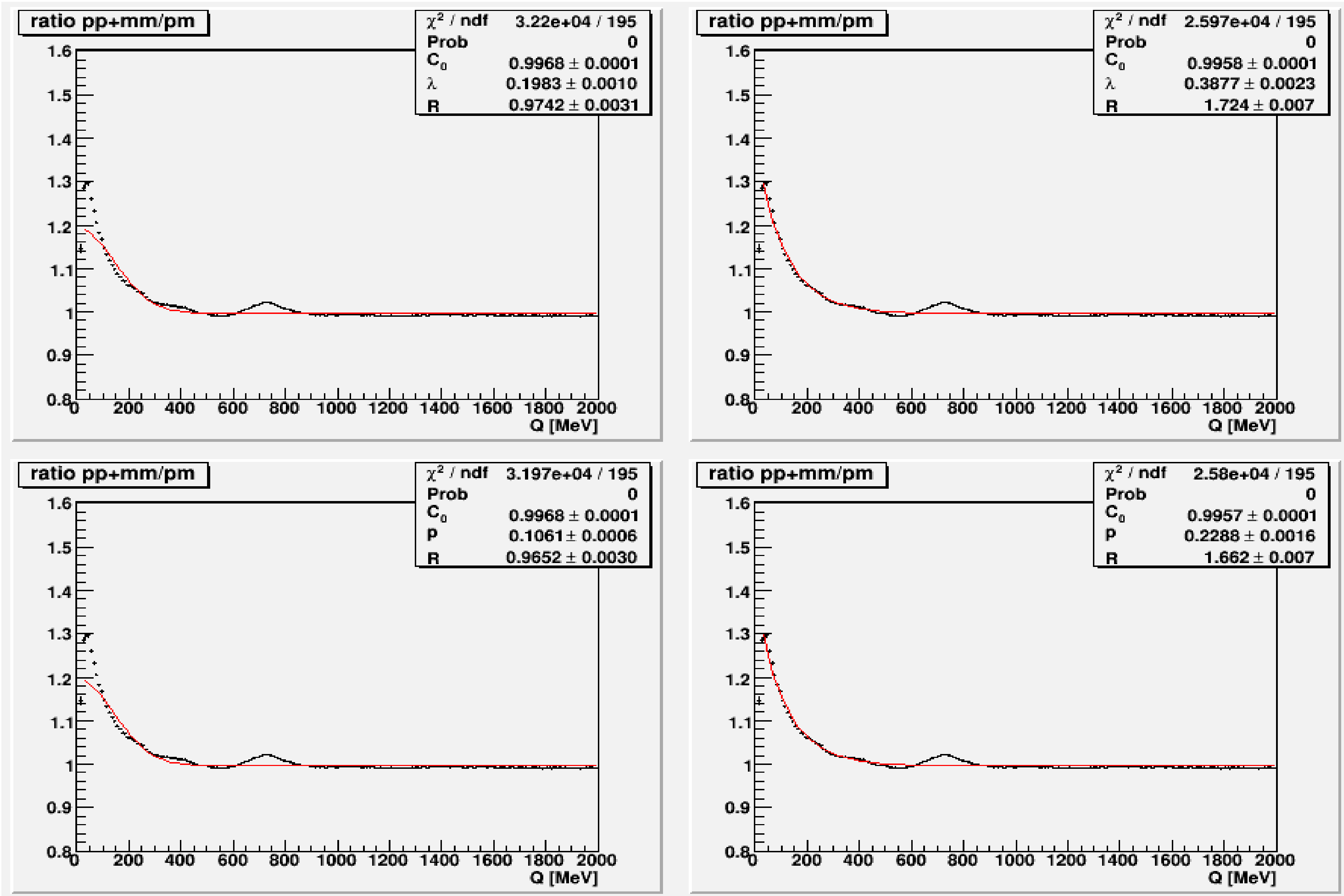
# 900 GeV : Data and Data corr. MC: C2 function fitting

**Coul. & eff. corrections, Pt > 200 MeV, Q > 20 MeV, Ntracks > 20 tracks, excluded interval (200-800)MeV from fit, first 4 fitting functions C2_1 - C2_4**



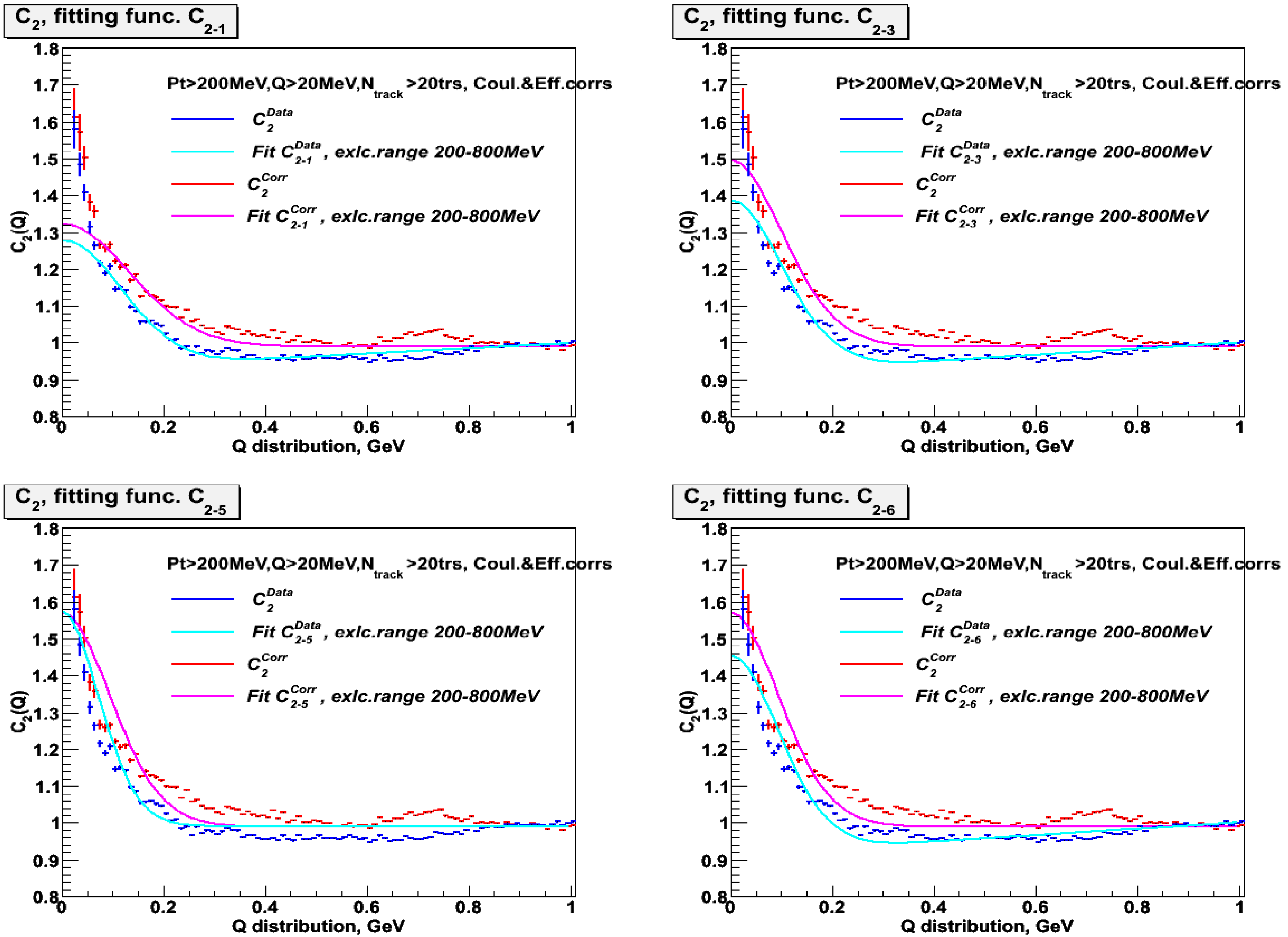
# 7 TeV : Data and Data corr. MC: C2 function fitting

**Coul. & eff. corrections, Pt > 200 MeV, Q > 20 MeV, Ntracks > 20 tracks, first 4 fitting functions C2_1 - C2_4**



# Data and Data corr. MC : C2 function fitting

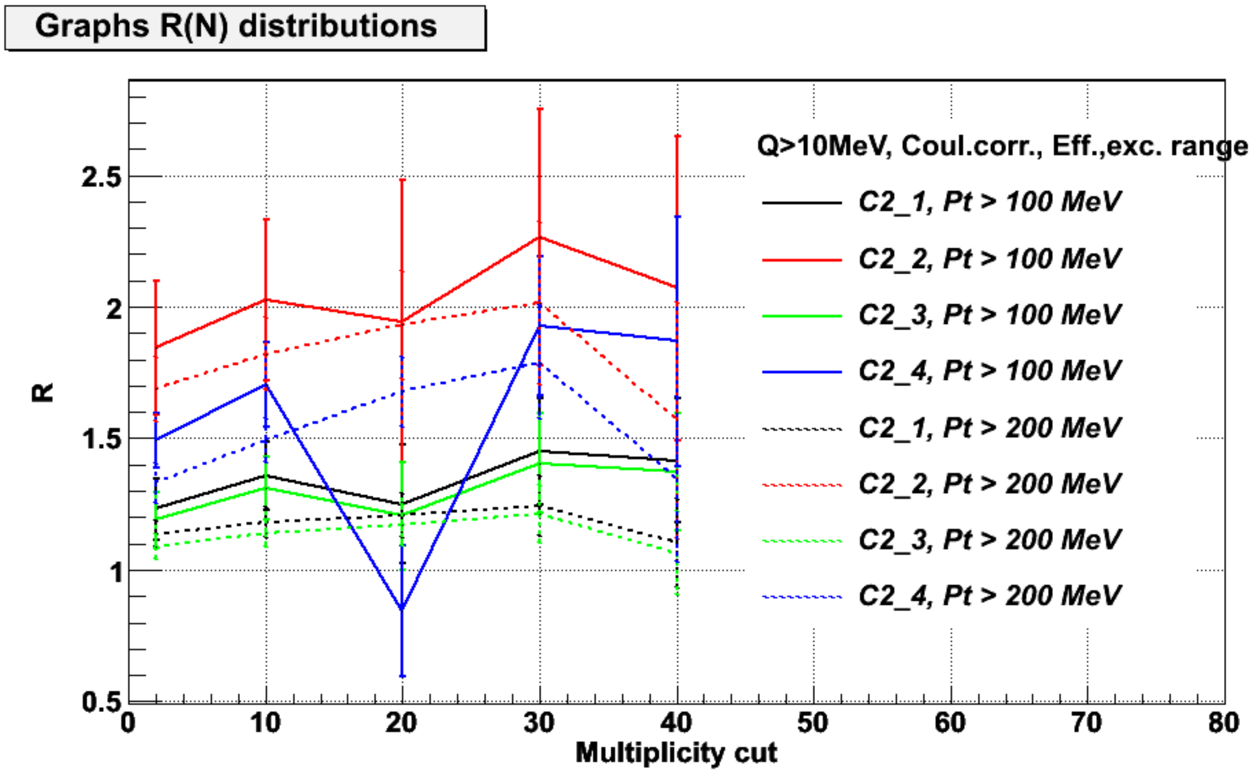
**Coul. & eff. corrections, Pt > 200 MeV, Q > 20 MeV, Ntracks > 20 tracks, excluded interval (200-800)MeV from fit, 4 fitting functions C2_1, C2_3, C2_5, C2_6**



# 900 GeV : Collisions data : Hadronisation Radius vs Multiplicity R(N)

## Diffr.corrections, Pt cuts = {100, 200} MeV, Q > 10 MeV, Multipl.Cuts = {2, 10, 20, 30, 40} tracks, excluded region (200-800MeV)

**Preliminary look!**




Very chaotic R(n)s' behaviour for full fitting interval.
We have better fit and fitting parameters for the case with bay's interval exclusion (200-800)MeV.

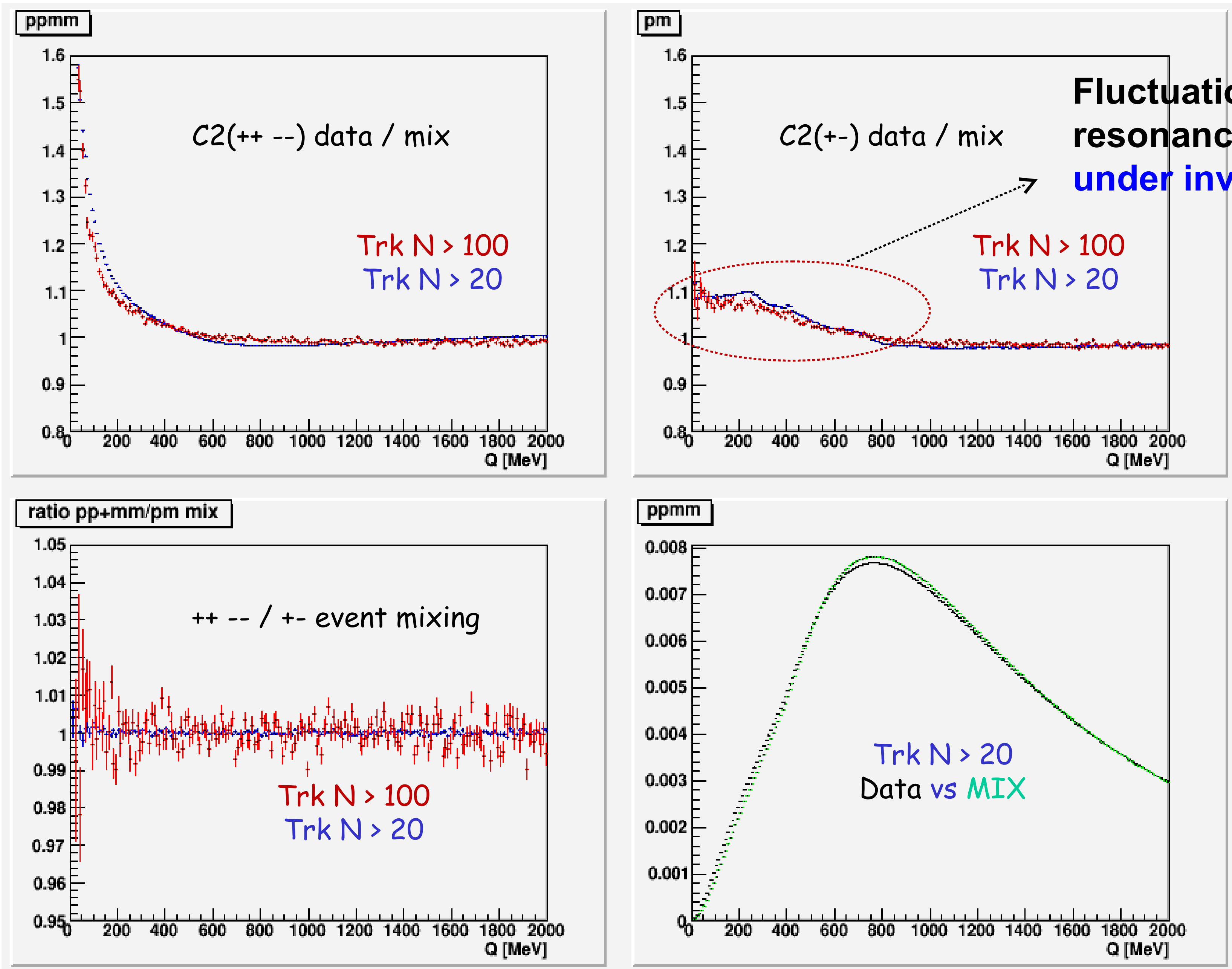
**R(C2_1), R(C2_3) = 1.0÷1.3** for N ={2,..40} tracks, exc.range

**R(C2_2), R(C2_4) = 1.5÷2.0** for N ={2,..40} tracks, exc.range

# 7 TeV: Q distributions, C2 functions,

## Event mixing reference sample

**Coul. & eff. corrections, Q > 10 MeV, Pt> 100 MeV, Ntracks cut > 20, 100 tracks**

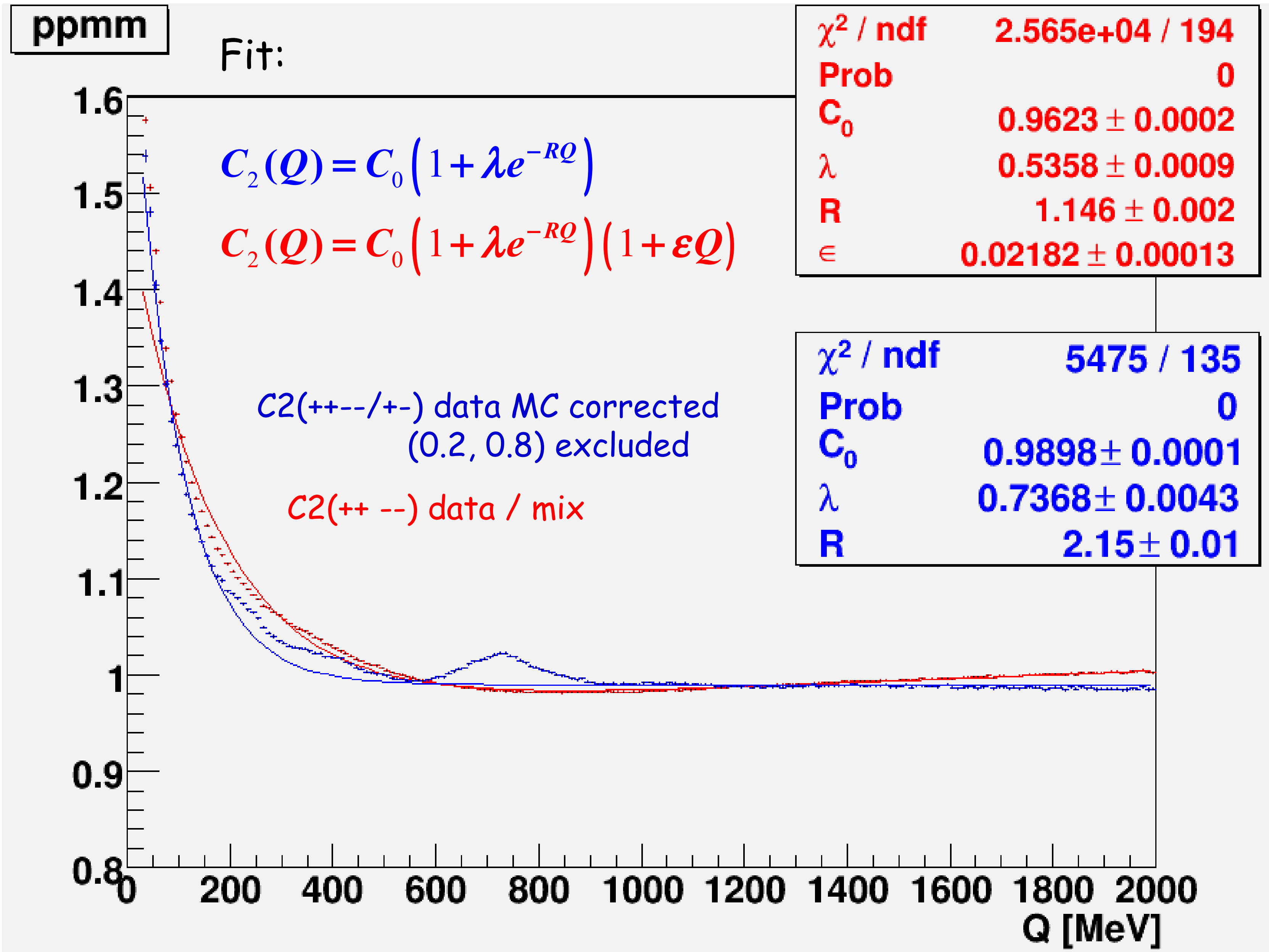



**Fluctuations caused by resonances and jets under investigation**

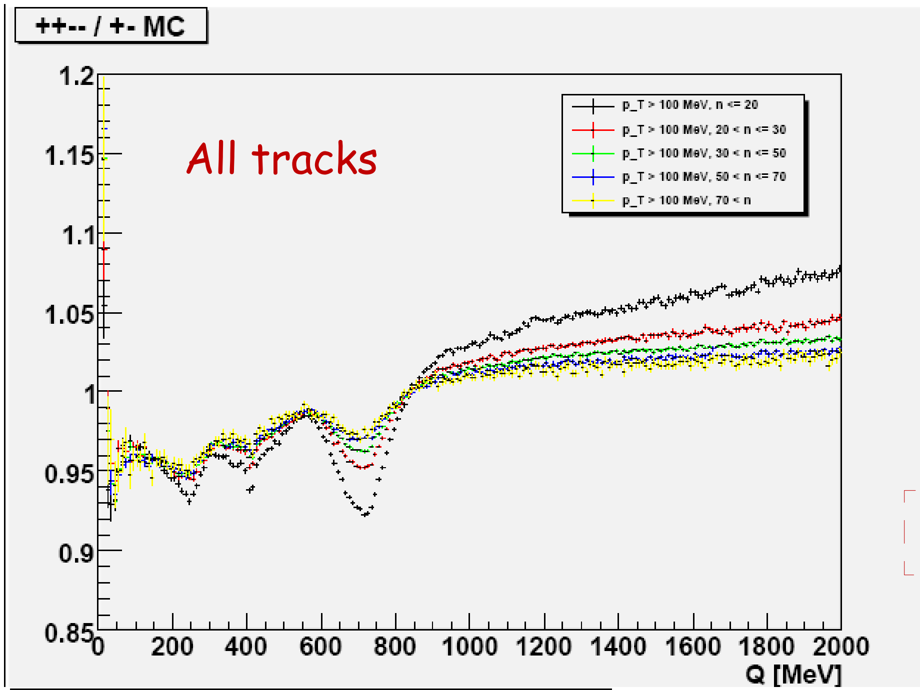
# 7 TeV: C2 functions,

## Data +- ref. sample vs Event mixing reference sample

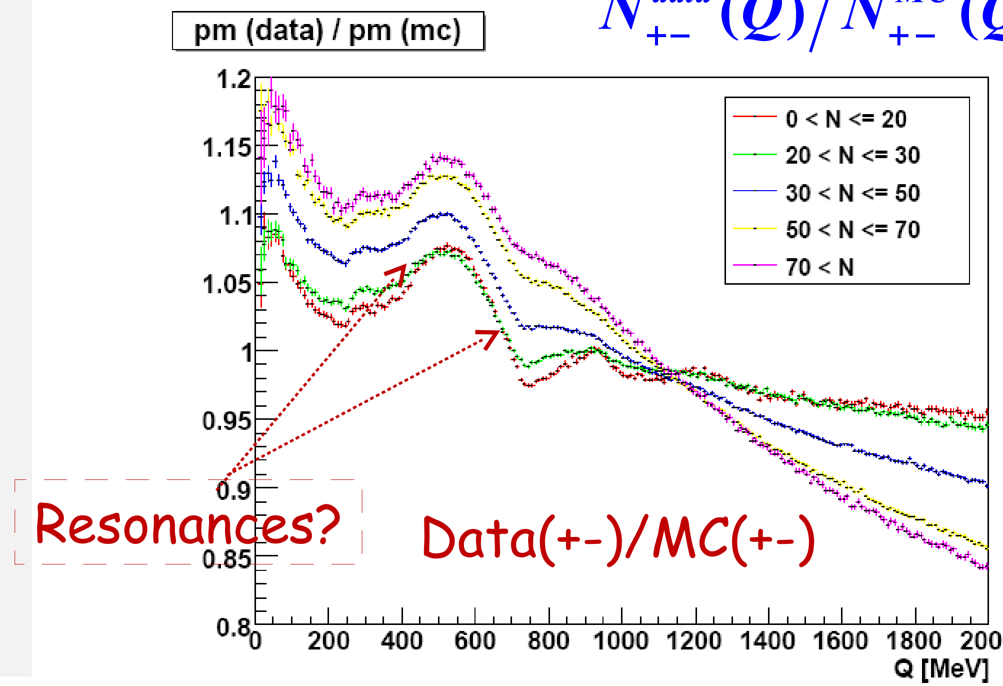
**Coul. & eff. corrections, Q > 10 MeV, Pt> 100 MeV, Ntracks cut > 20 tracks**

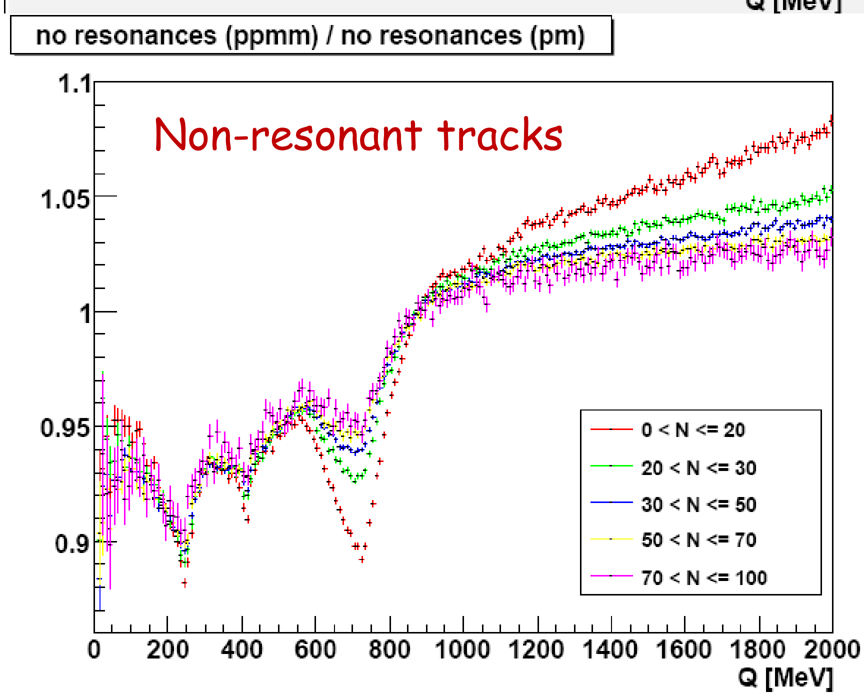


# 7 TeV: A look at Monte Carlo




$N_{+-}^{data}(Q)/N_{+-}^{MC}(Q)$




$N^{+-}(Q)/N_{MC}^{+-}(Q)$ should be 1

=> MC is not tuned to data !

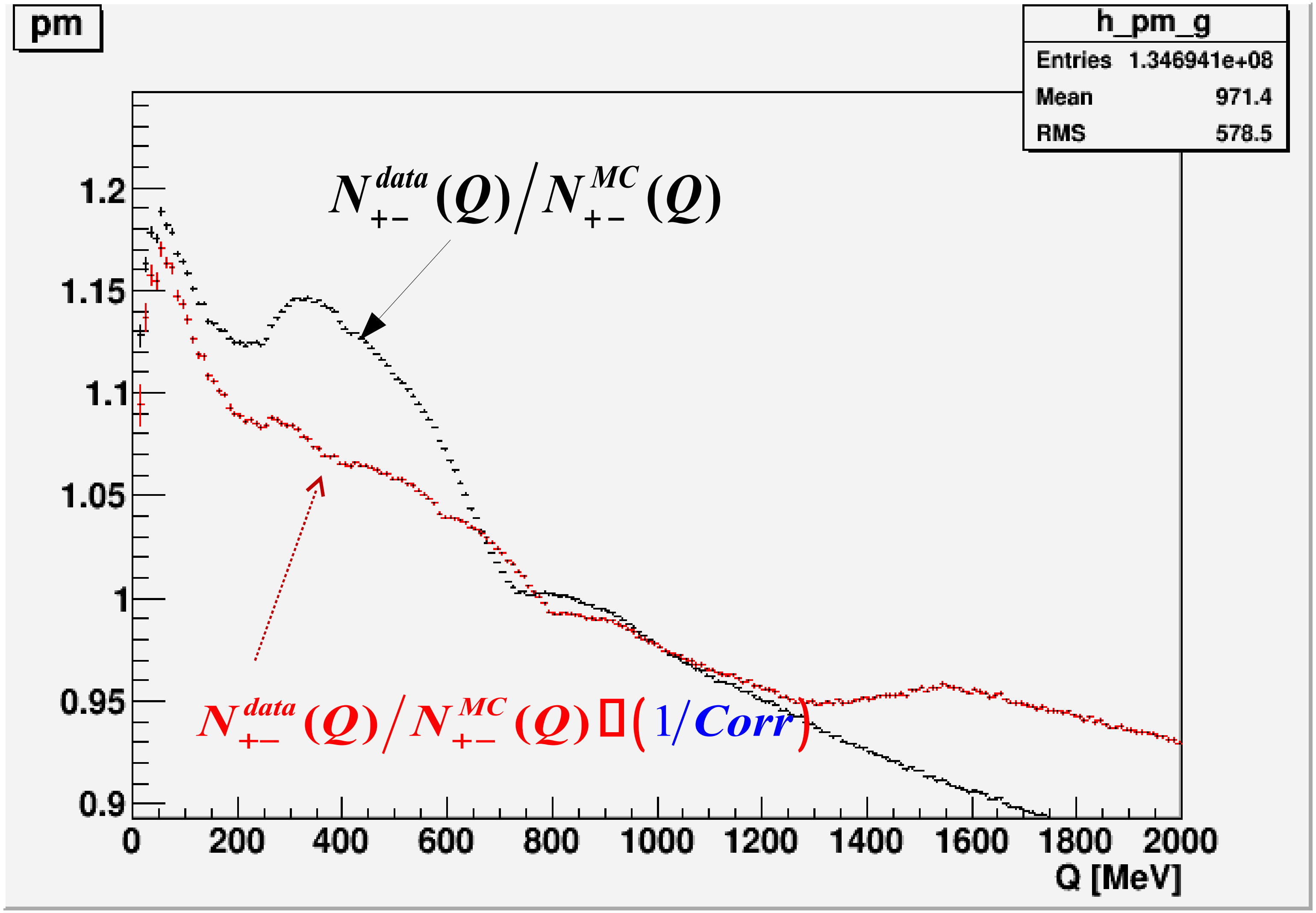
structure < 800 MeV

is not cased by resonances !

# 7 TeV: Q-ratio: data vs MC + resonance correction

**Coul. & eff. corrections, Q > 10 MeV, Pt> 100 MeV, Ntracks cut > 20 tracks**

**Resonance correction function:** $Corr = N_{+-}^{all}(Q) / N_{+-}^{non-res}(Q)$




**The idea was to express two pair track N(Q) as a superposition of resonant, non-resonant and jet parts – to understand the role of tracks from resonances and jets (Bratislava group's investigation).**

# Summary

•First round of Bose-Einstein correlations for ATLAS carried out

• Hadronization radius (R) and incoherence factor (λ,p) extracted for different reference functions:

• Same events +- track combinations

• Event mixing ++-- track combinations

• Opposite hemisphere technique with ++-- track combinations

• the first version of BEC document are created

• Todo list

• BEC studies with a restricted $\cos\theta$

• BEC studies using particle identification (waiting for Rel16 samples)

• Two-dimensional C2 correlation studies

• study of events with the high multiplicity trigger.

# Thank You For Your Attention!

# Backup slides

# 900 GeV Data: Hadronisation Radius — Different parametrizations of the C2 function

**Selections:** Qcut =20 MeV, Coulomb & efficiciency corrections

**Fit for full interval and except (200-800MeV) interval - «excluded range»**

| Pt cut | Qcut | N cut | R 1 ± errors | | | R 2 ± errors | | | R 3 ± errors | | | R 4 ± errors | | | R 5 ± errors | | | R 6 ± errors | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Full range for fit** | | | | | | | | | | | | | | | | | | | | |
| 100 | 20 | 2 | 0.69463 | ± | 0.03083 | 1.0287 | ± | 0.12546 | 0.8688 | ± | 0.0348 | 0.89309 | ± | 0.10757 | 2.00548 | ± | 0.22064 | 1.30889 | ± | 0.05683 |
| 100 | 20 | 10 | 0.83625 | ± | 0.02953 | 1.51568 | ± | 0.16176 | 0.96696 | ± | 0.03436 | 1.30523 | ± | 0.07893 | 2.14772 | ± | 0.26208 | 1.43486 | ± | 0.05626 |
| 100 | 20 | 20 | 0.93068 | ± | 0.05867 | 0.86185 | ± | 0.25401 | 1.20162 | ± | 0.0949 | 1.03843 | ± | 0.14619 | 2.24345 | ± | 0.21108 | 1.86355 | ± | 0.14633 |
| 100 | 20 | 30 | 1.19067 | ± | 0.09603 | 2.36075 | ± | 0.24987 | 1.3465 | ± | 0.06798 | 1.37777 | ± | 0.20302 | 2.42893 | ± | 0.29269 | 2.02786 | ± | 0.10662 |
| 100 | 20 | 40 | 1.32255 | ± | 0.20647 | 2.90782 | ± | 0.41517 | 1.41997 | ± | 0.1252 | 1.10409 | ± | 0.08766 | 2.53995 | ± | 0.45761 | 2.11745 | ± | 0.18141 |
| 200 | 20 | 2 | 0.7614 | ± | 0.03954 | 0.79672 | ± | 0.27276 | 0.95019 | ± | 0.04884 | 0.67198 | ± | 0.22278 | 1.70293 | ± | 0.10749 | 1.44267 | ± | 0.07976 |
| 200 | 20 | 10 | 0.843 | ± | 0.0319 | 1.33584 | ± | 0.19776 | 0.99239 | ± | 0.04965 | 1.22876 | ± | 0.12795 | 1.81672 | ± | 0.11269 | 1.51501 | ± | 0.09175 |
| 200 | 20 | 20 | 1.01842 | ± | 0.04382 | 0.8697 | ± | 0.28514 | 1.19932 | ± | 0.05357 | 1.47777 | ± | 0.25259 | 1.97626 | ± | 0.1432 | 1.77971 | ± | 0.08278 |
| 200 | 20 | 30 | 1.21279 | ± | 0.10826 | 2.5811 | ± | 0.37537 | 1.35991 | ± | 0.07401 | 1.64546 | ± | 0.2637 | 2.19205 | ± | 0.18614 | 2.00170 | ± | 0.11375 |
| 200 | 20 | 40 | 1.28159 | ± | 0.09313 | 1.87083 | ± | 0.79792 | 1.48993 | ± | 0.11121 | 1.80868 | ± | 0.3869 | 2.52752 | ± | 0.25113 | 2.21039 | ± | 0.17146 |
| 300 | 20 | 2 | 0.46462 | ± | 0.01918 | 0.5375 | ± | 0.01233 | 1.13533 | ± | 0.07515 | 0.2151 | ± | 0.02364 | 1.97251 | ± | 0.1655 | 1.69871 | ± | 0.11103 |
| 300 | 20 | 10 | 0.93499 | ± | 0.07803 | 0.49139 | ± | 0.013 | 1.20344 | ± | 0.07759 | 0.24285 | ± | 0.02563 | 2.12015 | ± | 0.17948 | 1.79341 | ± | 0.11617 |
| 300 | 20 | 20 | 1.1629 | ± | 0.05843 | 0.41147 | ± | 0.01331 | 1.3044 | ± | 0.06369 | 1.59395 | ± | 0.21918 | 2.49856 | ± | 0.24425 | 1.91170 | ± | 0.09805 |
| 300 | 20 | 30 | 1.47383 | ± | 0.14425 | 3.30235 | ± | 0.60597 | 1.55876 | ± | 0.09787 | 1.88823 | ± | 0.31771 | 2.58578 | ± | 0.27827 | 2.27839 | ± | 0.15079 |
| 300 | 20 | 40 | 1.69959 | ± | 0.32689 | 3.8301 | ± | 1.0868 | 1.82322 | ± | 0.18803 | 2.06635 | ± | 0.49418 | 2.85041 | ± | 0.36848 | 2.67596 | ± | 0.27806 |
| **Range (200-800) MeV excluded from fit** | | | | | | | | | | | | | | | | | | | | |
| 100 | 20 | 2 | 1.22726 | ± | 0.11633 | 1.83465 | ± | 0.25897 | 1.24911 | ± | 0.05734 | 1.48523 | ± | 0.10761 | 2.36059 | ± | 0.12773 | 1.88969 | ± | 0.08153 |
| 100 | 20 | 10 | 1.35019 | ± | 0.13289 | 2.01118 | ± | 0.31095 | 1.37996 | ± | 0.06343 | 1.69331 | ± | 0.16619 | 2.38236 | ± | 0.13666 | 2.06586 | ± | 0.09028 |
| 100 | 20 | 20 | 1.25273 | ± | 0.22786 | 1.94795 | ± | 0.54421 | 1.28621 | ± | 0.10085 | 1.56681 | ± | 0.17993 | 2.43528 | ± | 0.15443 | 1.92753 | ± | 0.1379 |
| 100 | 20 | 30 | 1.44978 | ± | 0.20427 | 2.26059 | ± | 0.49421 | 1.53437 | ± | 0.11972 | 1.92418 | ± | 0.26952 | 2.63092 | ± | 0.16301 | 2.30263 | ± | 0.17148 |
| 100 | 20 | 40 | 1.40933 | ± | 0.23738 | 2.0548 | ± | 0.58197 | 1.50294 | ± | 0.18222 | 1.85254 | ± | 0.47932 | 2.59818 | ± | 0.20819 | 2.20982 | ± | 0.26016 |
| 200 | 20 | 2 | 1.13477 | ± | 0.05066 | 1.68254 | ± | 0.12269 | 1.10952 | ± | 0.04306 | 1.32897 | ± | 0.07602 | 2.23919 | ± | 0.07432 | 1.62227 | ± | 0.06765 |
| 200 | 20 | 10 | 1.17967 | ± | 0.0572 | 1.81488 | ± | 0.14006 | 1.18578 | ± | 0.05026 | 1.49152 | ± | 0.08422 | 2.31503 | ± | 0.07501 | 1.73927 | ± | 0.0833 |
| 200 | 20 | 20 | 1.20492 | ± | 0.08204 | 1.92864 | ± | 0.20843 | 1.29147 | ± | 0.07439 | 1.67777 | ± | 0.13508 | 2.49101 | ± | 0.09704 | 1.92088 | ± | 0.12591 |
| 200 | 20 | 30 | 1.24051 | ± | 0.11552 | 2.00546 | ± | 0.31164 | 1.37425 | ± | 0.10195 | 1.78515 | ± | 0.22135 | 2.60686 | ± | 0.12888 | 2.05713 | ± | 0.16958 |
| 200 | 20 | 40 | 1.10001 | ± | 0.17103 | 1.5648 | ± | 0.45728 | 1.15893 | ± | 0.10699 | 1.34283 | ± | 0.32306 | 2.68884 | ± | 0.26618 | 1.72517 | ± | 0.15244 |
| 300 | 20 | 2 | 1.11227 | ± | 0.08095 | 1.6319 | ± | 0.20661 | 1.11359 | ± | 0.06033 | 1.32395 | ± | 0.11851 | 2.35762 | ± | 0.11502 | 1.65153 | ± | 0.0895 |
| 300 | 20 | 10 | 1.14772 | ± | 0.09171 | 1.73921 | ± | 0.23586 | 1.17145 | ± | 0.06929 | 1.43948 | ± | 0.13377 | 2.47774 | ± | 0.126 | 1.73607 | ± | 0.1044 |
| 300 | 20 | 20 | 1.16733 | ± | 0.10571 | 1.83842 | ± | 0.27125 | 1.23518 | ± | 0.07768 | 1.55796 | ± | 0.1453 | 2.71503 | ± | 0.16568 | 1.83842 | ± | 0.11881 |
| 300 | 20 | 30 | 1.10239 | ± | 0.18449 | 1.6926 | ± | 0.49251 | 1.15378 | ± | 0.12007 | 1.40383 | ± | 0.2409 | 2.8274 | ± | 0.2857 | 1.7223 | ± | 0.17098 |
| 300 | 20 | 40 | 1.09373 | ± | 0.24094 | 1.71643 | ± | 0.61621 | 1.21463 | ± | 0.14594 | 1.49189 | ± | 0.3503 | 3.12079 | ± | 0.38287 | 1.81716 | ± | 0.20962 |

# 900 GeV : Data corr. on MC: Hadronisation Radius — Different parametrizations of the C2 function

**Selections:** Qcut =20 MeV, Coulomb & eficiciency corrections

**Fit for full interval and except (200-800MeV) interval - «excluded range»**

| Pt cut | Qcut | N cut | R 1 ± errors | R 2 ± errors | R 3 ± errors | R 4 ± errors | R 5 ± errors | R 6 ± errors |
|---|---|---|---|---|---|---|---|---|
| **Full range for fit** | | | | | | | | |
| 100 | 20 | 2 | 0.81167 ± 0.02292 | 1.50526 ± 0.21228 | 0.89892 ± 0.02822 | 1.46017 ± 0.1724 | 1.31404 ± 0.0451 | 1.31404 ± 0.04528 |
| 100 | 20 | 10 | 0.8732 ± 0.04082 | 2.05297 ± 0.27343 | 0.96027 ± 0.04802 | 1.03443 ± 0.13817 | 1.40264 ± 0.07553 | 1.40264 ± 0.07588 |
| 100 | 20 | 20 | 0.97207 ± 0.05846 | 1.68342 ± 0.49727 | 1.12598 ± 0.08144 | 1.40769 ± 0.22761 | 1.67245 ± 0.13031 | 1.67245 ± 0.13089 |
| 100 | 20 | 30 | 0.97346 ± 0.0355 | 2.1326 ± 0.34856 | 1.03978 ± 0.03861 | 2.00601 ± 0.13041 | 1.4998 ± 0.05768 | 1.4998 ± 0.05787 |
| 100 | 20 | 40 | 0.99678 ± 0.07755 | 1.53374 ± 0.25607 | 1.31498 ± 0.09764 | 1.5508 ± 0.11993 | 1.98541 ± 0.14405 | 1.98541 ± 0.14471 |
| 200 | 20 | 2 | 0.76371 ± 0.04921 | 1.7021 ± 0.26002 | 0.80615 ± 0.03831 | 0.68804 ± 0.05676 | 1.33192 ± 0.06029 | 1.17058 ± 0.05843 |
| 200 | 20 | 10 | 0.87916 ± 0.07105 | 2.24907 ± 0.34843 | 0.9404 ± 0.06167 | 0.82569 ± 0.07282 | 1.51414 ± 0.10866 | 1.37799 ± 0.09575 |
| 200 | 20 | 20 | 0.90897 ± 0.03855 | 1.86071 ± 0.29198 | 1.03343 ± 0.04423 | 1.67438 ± 0.10033 | 1.51348 ± 0.06502 | 1.51348 ± 0.06515 |
| 200 | 20 | 30 | 1.00173 ± 0.0456 | 2.21531 ± 0.336 | 1.1159 ± 0.04877 | 1.88161 ± 0.13322 | 1.62491 ± 0.07081 | 1.62491 ± 0.07118 |
| 200 | 20 | 40 | 1.22697 ± 0.07521 | 2.8365 ± 0.33177 | 1.21591 ± 0.03864 | 1.17973 ± 0.125 | 1.75774 ± 0.05402 | 1.75774 ± 0.05441 |
| 300 | 20 | 2 | 0.80322 ± 0.02418 | 1.50656 ± 0.17798 | 0.9253 ± 0.02978 | 1.41824 ± 0.1064 | 1.3612 ± 0.04478 | 1.3612 ± 0.04501 |
| 300 | 20 | 10 | 0.85738 ± 0.0241 | 1.62747 ± 0.21373 | 0.97001 ± 0.02599 | 1.18555 ± 0.21071 | 1.41639 ± 0.03778 | 1.41639 ± 0.03795 |
| 300 | 20 | 20 | 0.88021 ± 0.03301 | 1.59041 ± 0.25462 | 1.01038 ± 0.03788 | 1.51976 ± 0.19476 | 1.48356 ± 0.05597 | 1.48356 ± 0.05591 |
| 300 | 20 | 30 | 0.8553 ± 0.03965 | 0.96075 ± 0.0514 | 1.03779 ± 0.04907 | 1.23165 ± 0.05663 | 1.54221 ± 0.07353 | 1.54221 ± 0.07381 |
| 300 | 20 | 40 | 1.06418 ± 0.03344 | 1.92914 ± 0.4153 | 1.16161 ± 0.03491 | 1.72913 ± 0.73781 | 1.68327 ± 0.05139 | 1.68327 ± 0.05162 |
| **Range (200-800) MeV excluded from fit** | | | | | | | | |
| 100 | 20 | 2 | 1.08519 ± 0.47772 | 0.25581 ± 0.04544 | 1.30521 ± 0.1426 | 0.19477 ± 0.03211 | 1.97296 ± 0.19208 | 1.97296 ± 0.1949 |
| 100 | 20 | 10 | 1.1549 ± 0.53048 | 0.34884 ± 0.05347 | 1.3428 ± 0.15248 | 0.24217 ± 0.03653 | 2.0191 ± 0.20491 | 2.0191 ± 0.20816 |
| 100 | 20 | 20 | 1.131 ± 0.44141 | 0.43724 ± 0.07321 | 1.40757 ± 0.15794 | 0.83819 ± 0.09828 | 2.12186 ± 0.21806 | 2.12186 ± 0.22111 |
| 100 | 20 | 30 | 1.27255 ± 0.33327 | 0.35487 ± 0.07868 | 1.48442 ± 0.16557 | 0.23994 ± 0.04757 | 2.25735 ± 0.23924 | 2.25735 ± 0.24129 |
| 100 | 20 | 40 | 1.02619 ± 0.09222 | 0.68395 ± 1.0667 | 1.34326 ± 0.08795 | 1.39207 ± 0.15223 | 2.01677 ± 0.1287 | 2.01677 ± 0.12963 |
| 200 | 20 | 2 | 1.0531 ± 0.19099 | 0.39061 ± 0.07577 | 1.18919 ± 0.07032 | 0.90637 ± 0.13828 | 1.78833 ± 0.09804 | 1.78833 ± 0.09895 |
| 200 | 20 | 10 | 1.06671 ± 0.22806 | 0.34218 ± 0.08241 | 1.21472 ± 0.08268 | 0.91338 ± 0.17640 | 1.82291 ± 0.11425 | 1.82291 ± 0.11556 |
| 200 | 20 | 20 | 1.0475 ± 0.35258 | 0.35994 ± 0.08261 | 1.2629 ± 0.12052 | 0.24004 ± 0.05085 | 1.89111 ± 0.16639 | 1.89111 ± 0.16886 |
| 200 | 20 | 30 | 1.12899 ± 0.27574 | 0.55688 ± 0.23892 | 1.35872 ± 0.09902 | 1.39981 ± 0.19417 | 2.0237 ± 0.13896 | 2.0237 ± 0.13354 |
| 200 | 20 | 40 | 1.26071 ± 0.1026 | 1.24287 ± 0.21872 | 1.4948 ± 0.09312 | 1.77903 ± 0.19987 | 2.19957 ± 0.13067 | 2.19957 ± 0.13206 |
| 300 | 20 | 2 | 0.9075 ± 0.35888 | 0.27845 ± 0.06572 | 1.18853 ± 0.10386 | 0.22649 ± 0.07534 | 1.79191 ± 0.14286 | 1.79191 ± 0.14488 |
| 300 | 20 | 10 | 0.94215 ± 0.33829 | 0.35769 ± 6.77261 | 1.23039 ± 0.1022 | 0.25061 ± 11.1899 | 1.84803 ± 0.14114 | 1.84803 ± 0.14276 |
| 300 | 20 | 20 | 1.01156 ± 0.11396 | 0.36385 ± 0.09582 | 1.30439 ± 0.09503 | 1.23736 ± 0.18594 | 1.9473 ± 0.13188 | 1.9473 ± 0.1334 |
| 300 | 20 | 30 | 1.09664 ± 0.12704 | 0.41853 ± 0.15318 | 1.36839 ± 0.10901 | 1.42084 ± 0.22277 | 2.03056 ± 0.15084 | 2.03056 ± 0.14407 |
| 300 | 20 | 40 | 1.02325 ± 0.24873 | 0.54973 ± 0.12225 | 1.37671 ± 0.23035 | 1.37861 ± 0.46796 | 2.20624 ± 0.20467 | 2.08309 ± 0.32724 |

# 7TeV : C2 fit vs Ntracks cuts

**Qmin =20 MeV, (0,0)- full fitted interval, (0.2,0.8) GeV - the interval not included**

| trk pTcut=100MeV | | | f1(Q) | | | f2(Q) | | | f3(Q) | | | f4(Q) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NtrkCut | from | to | R | | | R | | | R | | | R | | |
| 0 | 0 | 0 | 1.305 | ± | 0.0015 | 2.470 | ± | 0.004 | 1.275 | ± | 0.001 | 1.210 | ± | 0.002 |
| 0 | 0.2 | 0.8 | 1.589 | ± | 0.0022 | 2.782 | ± | 0.006 | 1.542 | ± | 0.002 | 1.974 | ± | 0.009 |
| 20 | 0 | 0 | 1.413 | ± | 0.0019 | 2.696 | ± | 0.005 | 1.380 | ± | 0.002 | 1.316 | ± | 0.003 |
| 20 | 0.2 | 0.8 | 1.670 | ± | 0.0026 | 2.992 | ± | 0.007 | 1.622 | ± | 0.002 | 1.960 | ± | 0.012 |
| 50 | 0 | 0 | 1.574 | ± | 0.0037 | 3.029 | ± | 0.009 | 1.539 | ± | 0.003 | 1.550 | ± | 0.007 |
| 50 | 0.2 | 0.8 | 1.804 | ± | 0.0046 | 3.335 | ± | 0.012 | 1.756 | ± | 0.004 | 1.958 | ± | 0.017 |
| 100 | 0 | 0 | 1.744 | ± | 0.0201 | 3.368 | ± | 0.046 | 1.708 | ± | 0.019 | 1.881 | ± | 0.050 |
| 100 | 0.2 | 0.8 | 1.938 | ± | 0.0236 | 3.613 | ± | 0.060 | 1.890 | ± | 0.022 | 2.168 | ± | 0.079 |

| Trk pTcut=200MeV | | | f1(Q) | | | f2(Q) | | | f3(Q) | | | f4(Q) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NtrkCut | from | to | R | | | R | | | R | | | R | | |
| 0 | 0 | 0 | 1.319 | ± | 0.0021 | 2.463 | ± | 0.005 | 1.288 | ± | 0.002 | 1.231 | ± | 0.004 |
| 0 | 0.2 | 0.8 | 1.607 | ± | 0.0030 | 2.799 | ± | 0.008 | 1.562 | ± | 0.003 | 2.229 | ± | 0.005 |
| 20 | 0 | 0 | 1.467 | ± | 0.0027 | 2.794 | ± | 0.006 | 1.434 | ± | 0.003 | 1.303 | ± | 0.004 |
| 20 | 0.2 | 0.8 | 1.727 | ± | 0.0038 | 3.106 | ± | 0.010 | 1.682 | ± | 0.004 | 2.374 | ± | 0.013 |
| 50 | 0 | 0 | 1.668 | ± | 0.0056 | 3.240 | ± | 0.013 | 1.631 | ± | 0.005 | 1.473 | ± | 0.007 |
| 50 | 0.2 | 0.8 | 1.904 | ± | 0.0072 | 3.545 | ± | 0.019 | 1.857 | ± | 0.007 | 2.160 | ± | 0.033 |
| 100 | 0 | 0 | 1.872 | ± | 0.0371 | 3.700 | ± | 0.087 | 1.834 | ± | 0.035 | 1.753 | ± | 0.049 |
| 100 | 0.2 | 0.8 | 2.133 | ± | 0.0456 | 4.087 | ± | 0.118 | 2.083 | ± | 0.043 | 2.260 | ± | 0.126 |

**Increase of R with the cut on trk multiplicity (expected) and Pt (weak)!**

# 7TeV : C2 fit vs Ntracks cuts; Data corr. MC

**Qmin =20 MeV, (0,0)- full fitted interval, (0.2,0.8) GeV - the interval not included**

| Ptcut =200MeV | | | | f1(Q) | | | f2(Q) | | | f3(Q) | | | f4(Q) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NtrCut | Qmin | from | to | R | | | R | | | R | | | R | | |
| 0 | 20 | 0 | 0 | 0.930 | ± | 0.002 | 1.665 | ± | 0.006 | 0.921 | ± | 0.002 | 1.598 | ± | 0.005 |
| 0 | 20 | 0.2 | 0.8 | 1.212 | ± | 0.004 | 1.733 | ± | 0.011 | 1.187 | ± | 0.004 | 1.620 | ± | 0.010 |
| 20 | 20 | 0 | 0 | 0.974 | ± | 0.003 | 1.724 | ± | 0.007 | 0.965 | ± | 0.003 | 1.662 | ± | 0.007 |
| 20 | 20 | 0.2 | 0.8 | 1.271 | ± | 0.005 | 1.896 | ± | 0.013 | 1.247 | ± | 0.005 | 1.780 | ± | 0.012 |
| 50 | 20 | 0 | 0 | 0.963 | ± | 0.008 | 1.617 | ± | 0.017 | 0.956 | ± | 0.007 | 1.576 | ± | 0.016 |
| 50 | 20 | 0.2 | 0.8 | 1.354 | ± | 0.011 | 2.133 | ± | 0.028 | 1.332 | ± | 0.010 | 2.012 | ± | 0.025 |
| 100 | 20 | 0 | 0 | 1.351 | ± | 0.194 | 1.748 | ± | 0.626 | 1.335 | ± | 0.189 | 1.741 | ± | 0.586 |
| 100 | 20 | 0.2 | 0.8 | 1.690 | ± | 0.170 | 3.343 | ± | 0.582 | 1.663 | ± | 0.167 | 3.029 | ± | 0.315 |

| Fit: | $C_2(Q)=1+\lambda exp(-Q^2R^2)$ | | $C_2(Q)=1+2p(1-p)exp(-Q^2R^2)+p^2exp(-Q^2R^2)$ | |
|---|---|---|---|---|
| N | pT >100 | pT >500 | pT >100 | pT >500 |
| - | R | | R | |
| 20-Feb | 0.925 ±0.003 | 1.116 ±0.009 | 0.893 ±0.003 | 1.079 ±0.008 |
| 20 - 30 | 1.211 ±0.006 | 1.455 ±0.015 | 1.180 ±0.006 | 1.413 ±0.014 |
| 30 - 50 | 1.380 ±0.006 | 1.546 ±0.017 | 1.349 ±0.005 | 1.510 ±0.016 |
| 50 - 70 | 1.521 ±0.009 | 1.656 ±0.044 | 1.489 ±0.008 | 1.621 ±0.042 |
| 70 - ∞ | 1.678 ±0.014 | 1.617 ±0.137 | 1.643 ±0.013 | 1.591 ±0.132 |

Fit: $C_2(Q) = 1 + \lambda e^{-Q^2R^2}$

| | C2 functions: hadronization radius, R, pT >100 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | C2_fit_full | | | C2_fit_excl | | | **C2_MCcor** | | | **C2_EvMix** | | |
| 0 - 20 | 0.925 | ± | 0.003 | 1.229 | ± | 0.008 | **0.975** | **±** | **0.004** | **0.629** | **±** | **0.002** |
| 20 - 30 | 1.211 | ± | 0.006 | 1.477 | ± | 0.010 | **1.082** | **±** | **0.006** | **0.710** | **±** | **0.003** |
| 30 - 50 | 1.380 | ± | 0.006 | 1.636 | ± | 0.008 | **1.080** | **±** | **0.005** | **0.766** | **±** | **0.003** |
| 50 - 70 | 1.521 | ± | 0.009 | 1.750 | ± | 0.011 | **1.033** | **±** | **0.008** | **0.833** | **±** | **0.005** |
| 70 - ∞ | 1.678 | ± | 0.014 | 1.889 | ± | 0.016 | **0.974** | **±** | **0.016** | **0.906** | **±** | **0.008** |

# 900 GeV data samples

## Experimental data samples:

*data09_900GeV.00142383.physics_MinBias.merge.ESDtoD3PD.r1093_p101_tid120524_00_r15.6.7.8Newtrk
•data09_900GeV.00142195.physics_MinBias.merge.ESDtoD3PD.r1093_p101_tid120485_00_r15.6.7.8Newtrk
•data09_900GeV.00142193.physics_MinBias.merge.ESDtoD3PD.r1093_p101_tid120419_00_r15.6.7.8Newtrk
•data09_900GeV.00142191.physics_MinBias.merge.ESDtoD3PD.r1093_p101_tid120365_00_r15.6.7.8Newtrk
•data09_900GeV.00142189.physics_MinBias.merge.ESDtoD3PD.r1093_p101_tid120305_00_r15.6.7.8Newtrk
•data09_900GeV.00142174.physics_MinBias.merge.ESDtoD3PD.r1093_p101_tid120272_00_r15.6.7.8Newtrk
•data09_900GeV.00142171.physics_MinBias.merge.ESDtoD3PD.r1093_p101_tid120239_00_r15.6.7.8Newtrk
•data09_900GeV.00142166.physics_MinBias.merge.ESDtoD3PD.r1093_p101_tid120206_00_r15.6.7.8Newtrk
*data09_900GeV.00142165.physics_MinBias.merge.ESDtoD3PD.r1093_p101_tid120173_00_r15.6.7.8Newtrk
*data09_900GeV.00142154.physics_MinBias.merge.ESDtoD3PD.r1093_p101_tid120032_00_r15.6.7.8NewtrkGLS
•data09_900GeV.00142149.physics_MinBias.merge.ESDtoD3PD.r1093_p101_tid119999_00_r15.6.7.8Newtrk
•data09_900GeV.00141811.physics_MinBias.merge.ESDtoD3PD.r1093_p101_tid119768_00_r15.6.7.8Newtrk
•data09_900GeV.00141749.physics_MinBias.merge.ESDtoD3PD.r1093_p101_tid119702_00_r15.6.7.8Newtrk

**Number of selected events = 357,523**
**Number of selected tracks = 4,532,663**

## MC data sample: (non-diffractive)

mc09_900GeV.105001.pythia_minbias.merge.NTUP_MINBIAS.e500_s771_s767_r1234_p137_tid130221_00

**Number of selected events = 975,742**
**Number of selected tracks = 12,363,168**

# 7 TeV data samples

Experimental data samples:

data10_7TeV.00152221.physics_MinBias.merge.NTUP_MINBIAS.f239_p127_tid125125_00

data10_7TeV.00152166.physics_MinBias.merge.NTUP_MINBIAS.f239...

data10_7TeV.00152214.physics_MinBias.merge.NTUP_MINBIAS.f239...

data10_7TeV.00152345.physics_MinBias.merge.NTUP_MINBIAS.f239...

data10_7TeV.00152409.physics_MinBias.merge.NTUP_MINBIAS.f239...

data10_7TeV.00152441.physics_MinBias.merge.NTUP_MINBIAS.f239...

data10_7TeV.00152508.physics_MinBias.merge.NTUP_MINBIAS.f241...

Nr. Of selected events: about 10 M events

MC sample: ( non-difractive samples)

mc09_7TeV.105001.pythia_minbias.merge.NTUP_MINBIAS.e517_s764_s767_r1229_p137

Nr. Of selected events: about 14 M events

## *7 TeV Data with the high multiplicity trigger*

**Experimental data samples:**

**user.jmonk.00166850.physics.MinBias.NTUP_HIGHMULT.f296.v2/**

***Number of selected events = 13,985***

***Number of selected tracks = 2,070,633***

# Event/track selections for 7 TeV data sample with the high multiplicity trigger**

**Trigger: mbSpTrkVtxMh**

**Another Luminosity blocks**

**Vertex:**
**at least one good primary vertex (type 1). Removed pile-up cut as defined by the MB 2.0 analysis. Instead if second vertex has higher multiplicity than the primary, skip event.**

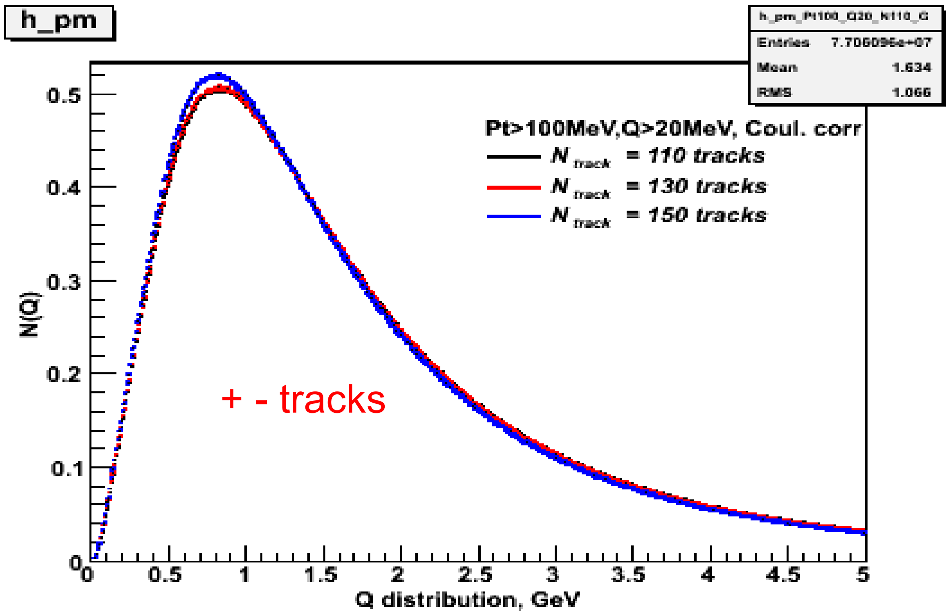
**At least 108 tracks with:**
- ➡ $|\eta| < 2.5$
- ➡ pt > 100 MeV
- ➡ Reconstructed by the inside-out or low-pt tracking algorithms.
- ➡ ≥ 1 pixel hit*
- ➡ ≥ 6 SCT hits
- ➡ $|d0| < 1.5$ mm
- ➡ $|z0\sin\theta| < 1.5$ mm
- ➡ fit probability ≥ 0.01 for pt > 10 GeV

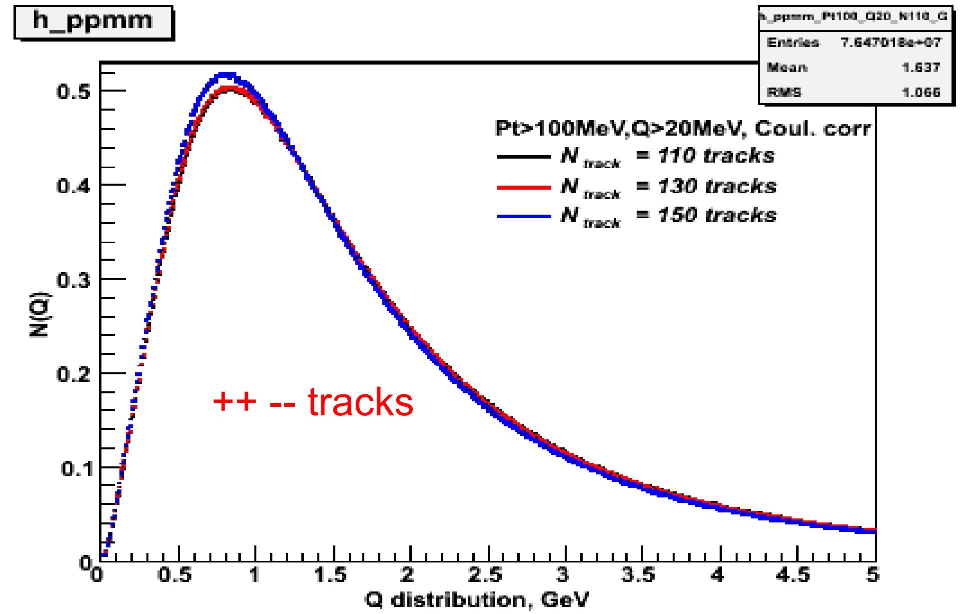
* *No b-layer requirement. After MB 2.0 definition of expectHitInBLayer changed.*

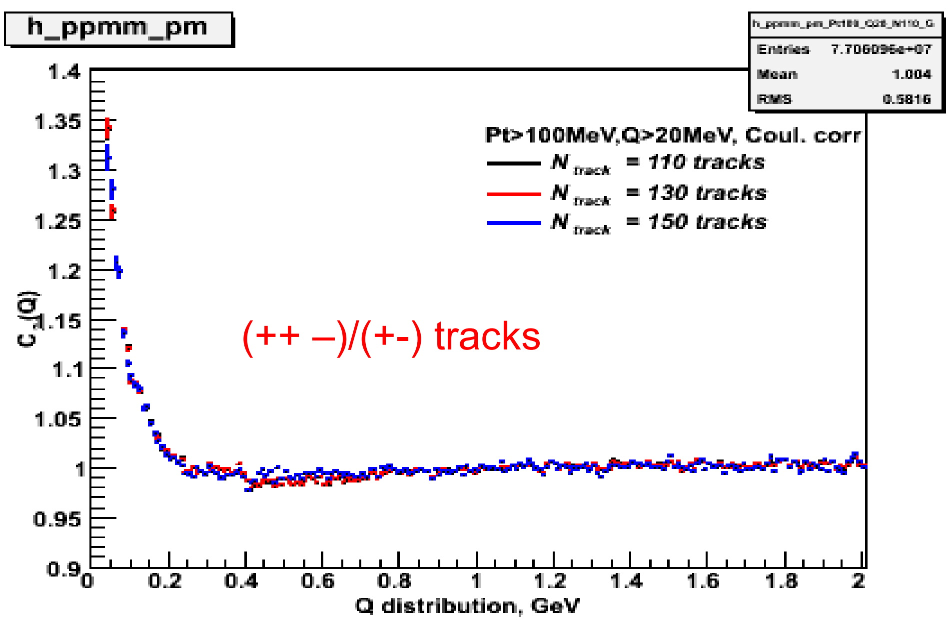
**http://indico.cern.ch/getFile.py/access?contribId=6&resId=0&materialId=slides&confId=106091

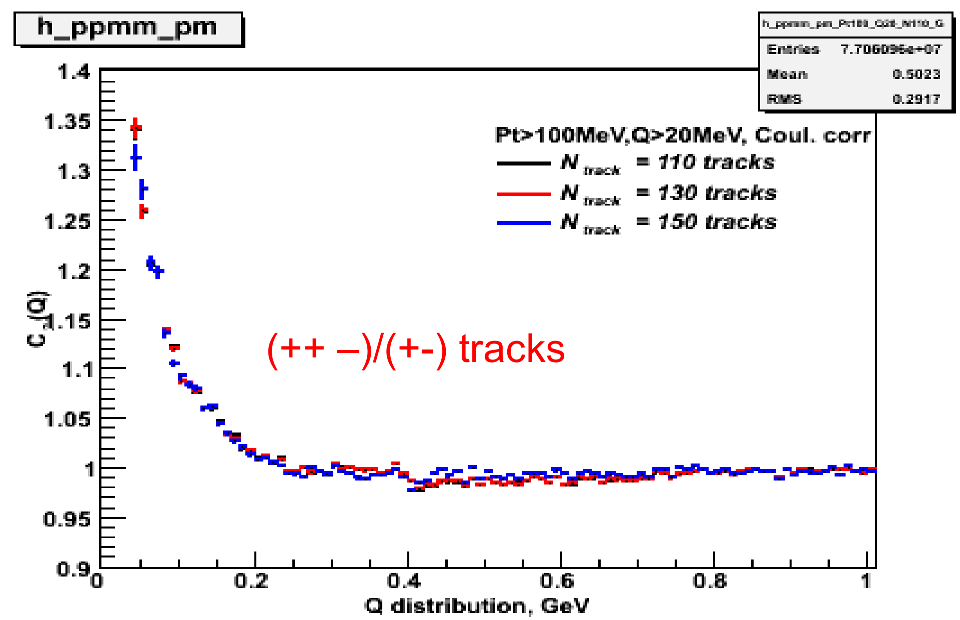
# Q distributions, C2 functions, Ntracks Cuts

## 7 TeV data : Coulomb correction, Pt > 100 MeV, Q > 20 MeV



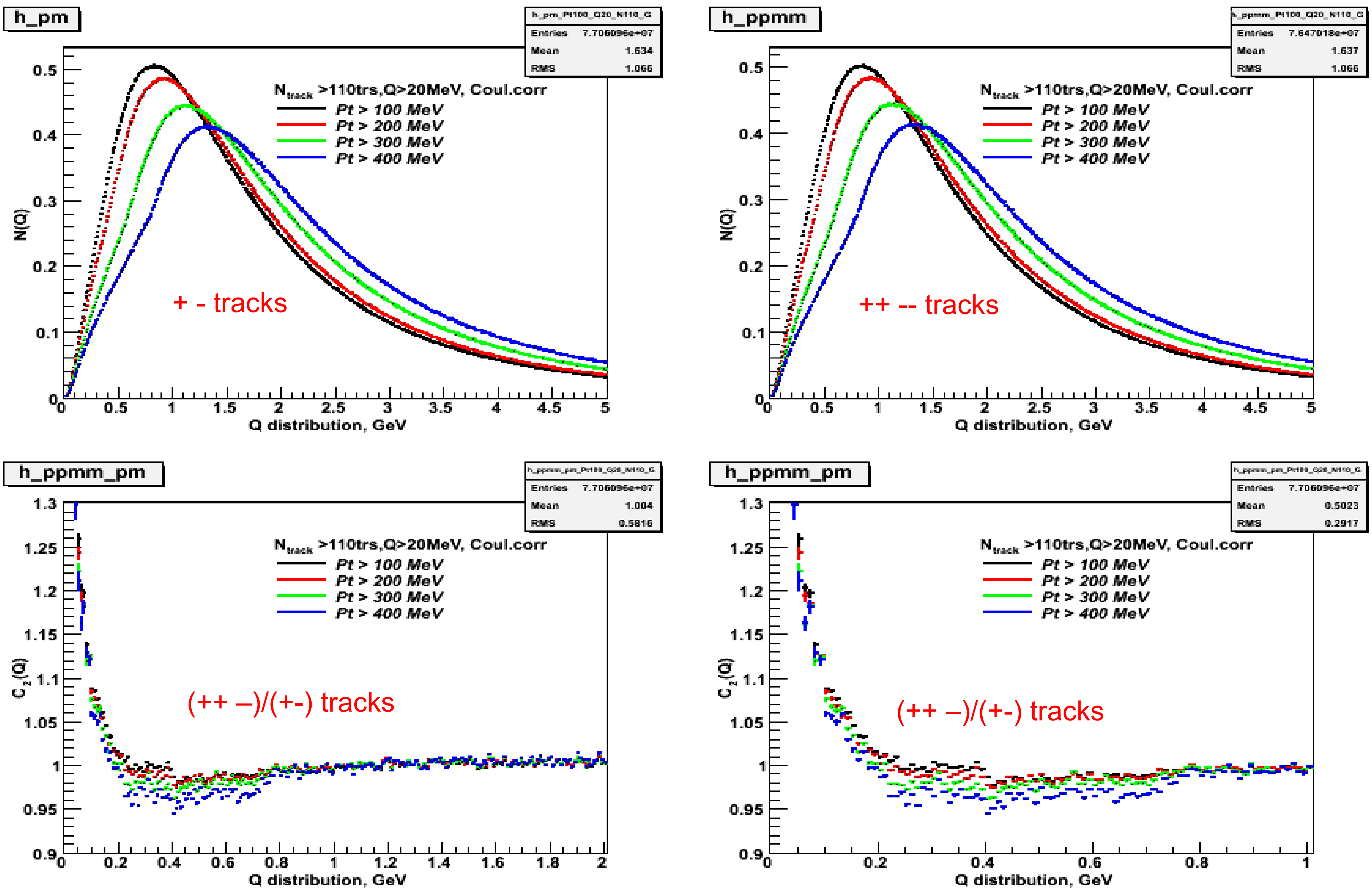






*No dependence of the C2 parameters on the high multiplicity cuts!*

# Q distributions, C2 functions, Pt Cuts

## 7 TeV data : Coulomb correction, Q > 20 MeV, Ntracks cut > 110 tracks



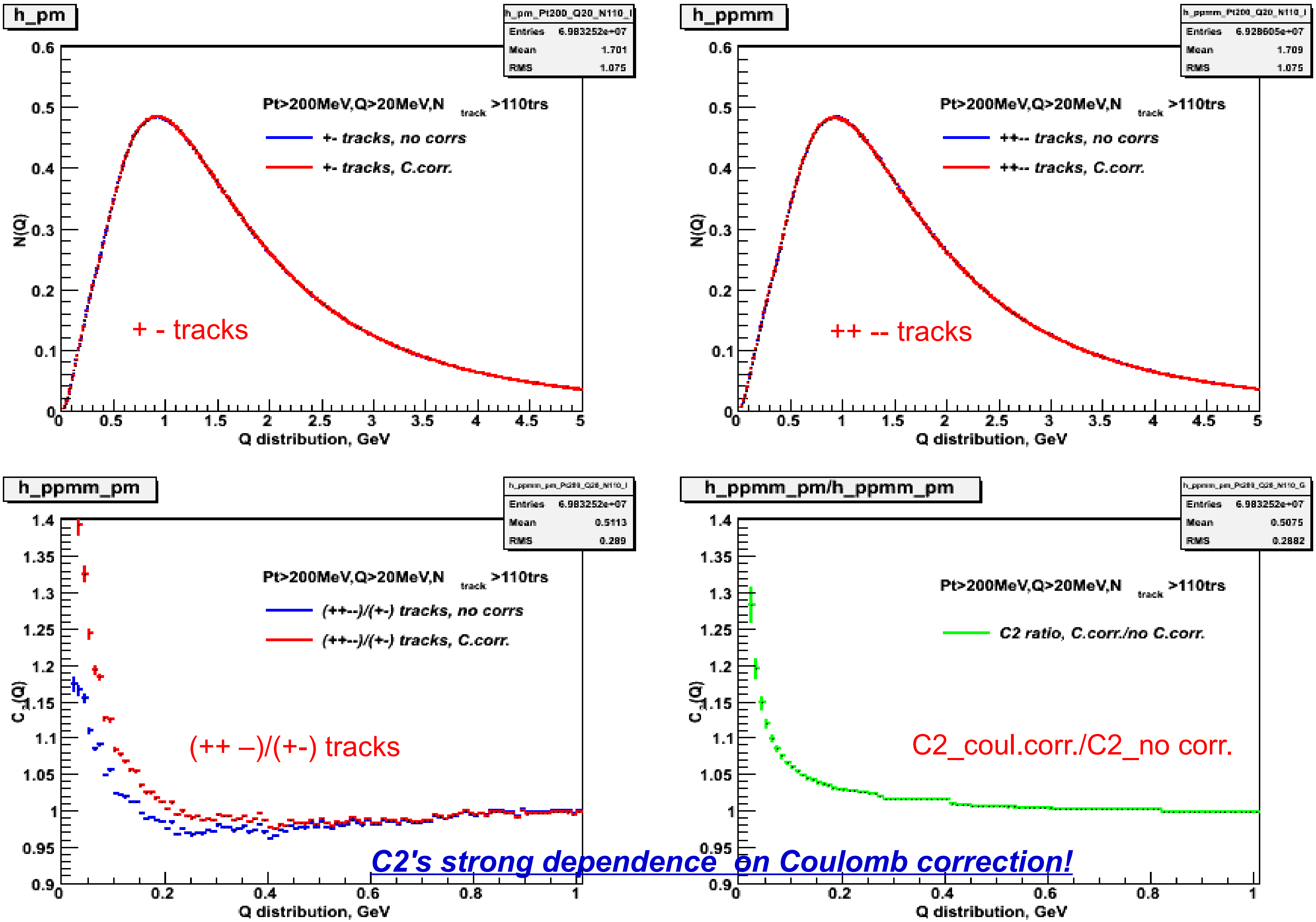

*Strong dependence of the C2 parameters on the pt cuts!*

*For low pt cut (ex. 100 MeV) The drop in the C2 function is (almost) disappeared!*

# Q distributions, C2 functions

## 7 TeV data : With/ without Coulomb correction

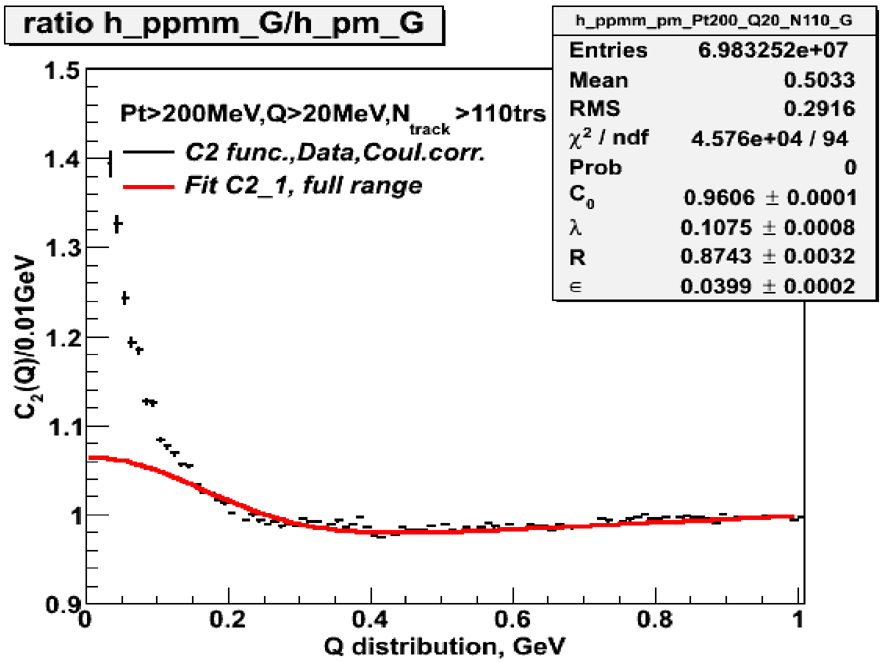
## Pt> 200 MeV, Q > 20 MeV, Ntracks > 110 tracks

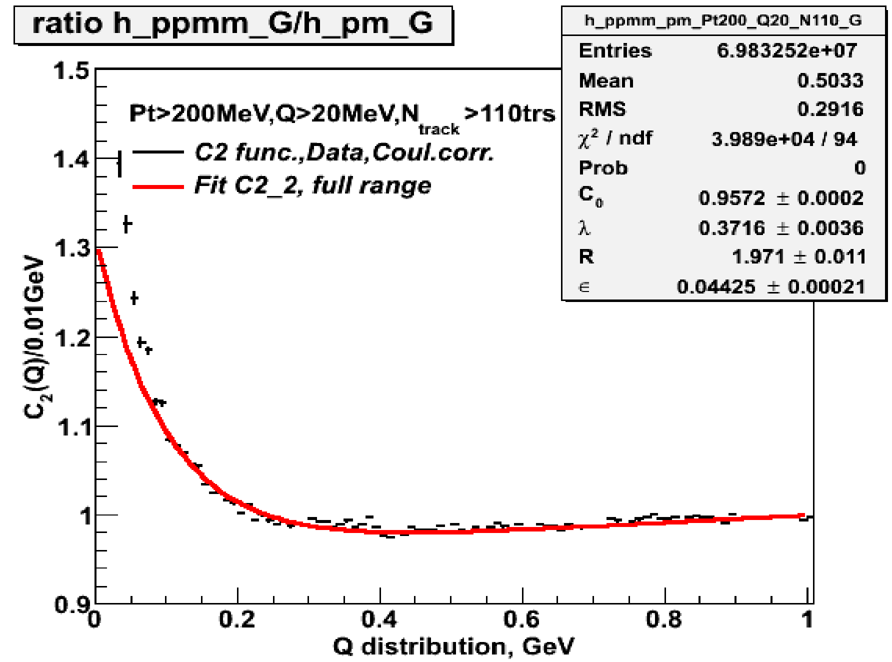


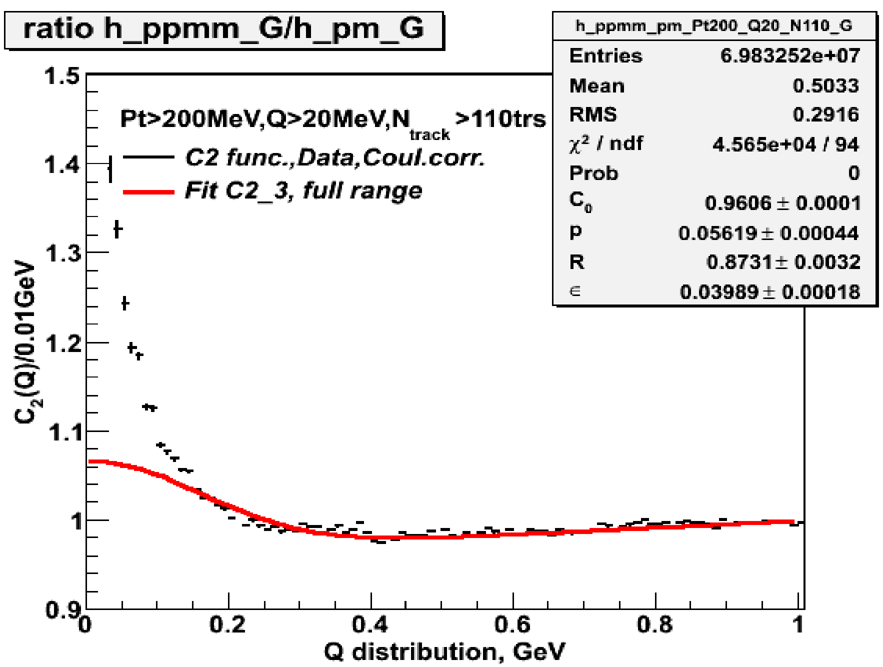

***C2's strong dependence on Coulomb correction!***

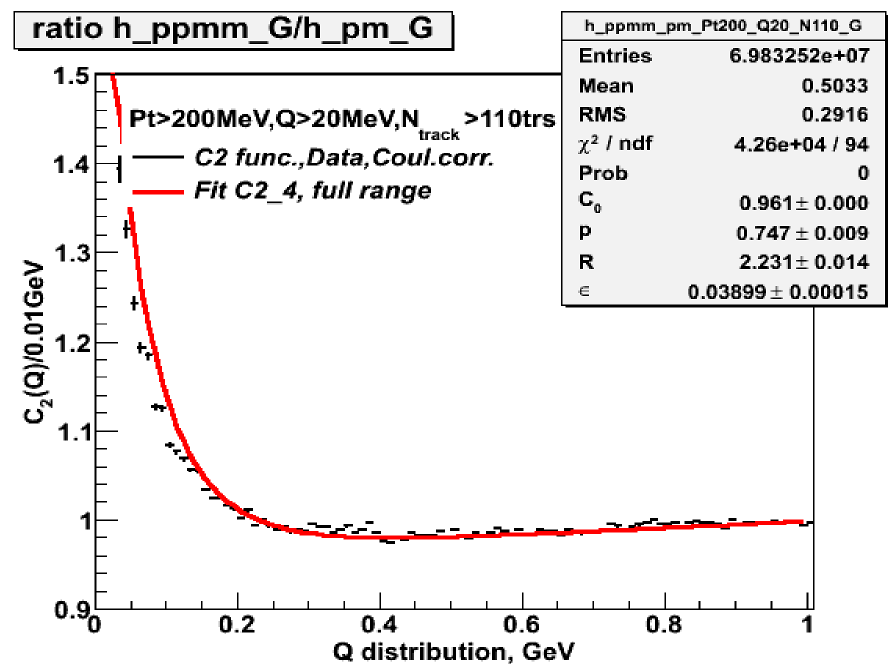
# 7 TeV data : C2 fit funs: C2_1,C2_2, C2_3, C2_4

## Coulomb correction, Pt> 200 MeV, Q > 20 MeV, Ntracks > 110 tracks, full fitting interval



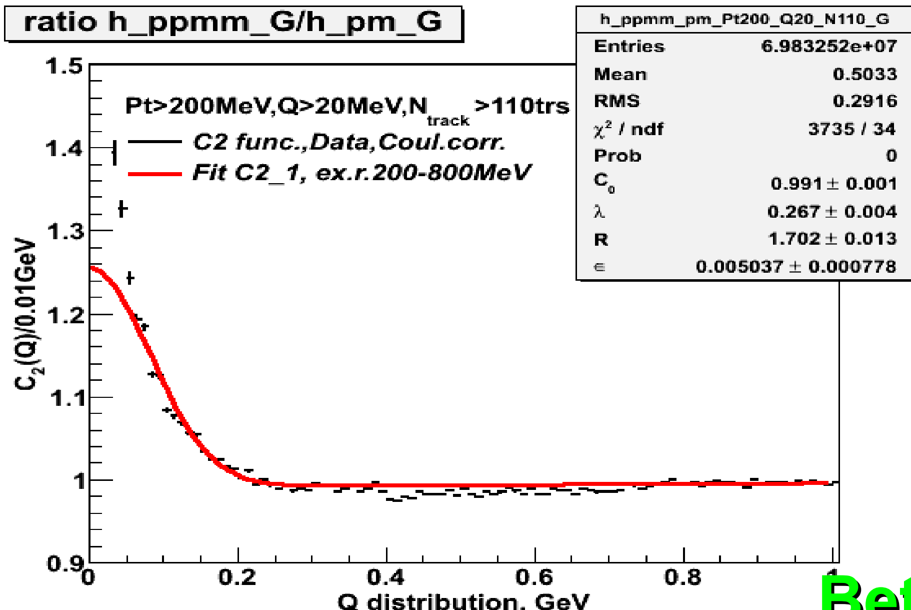



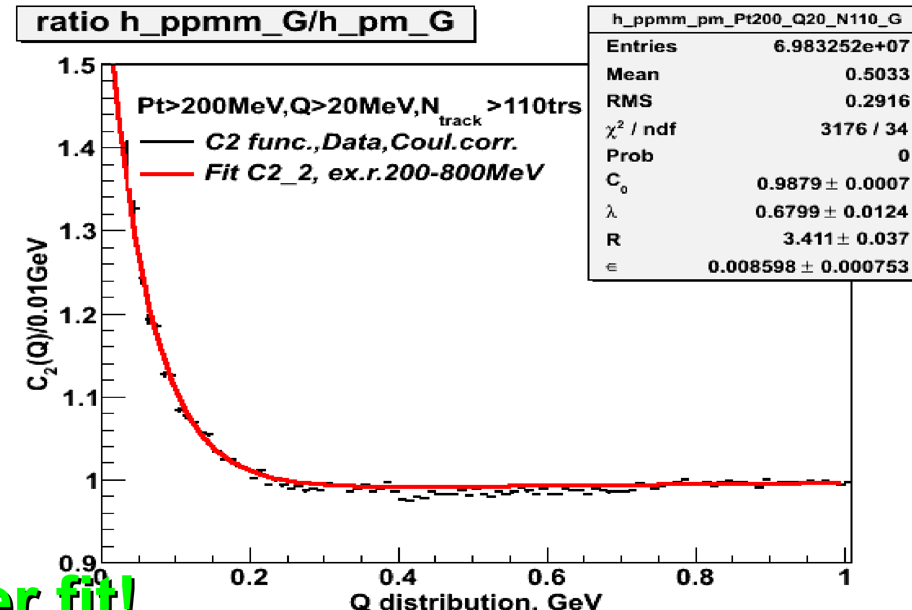



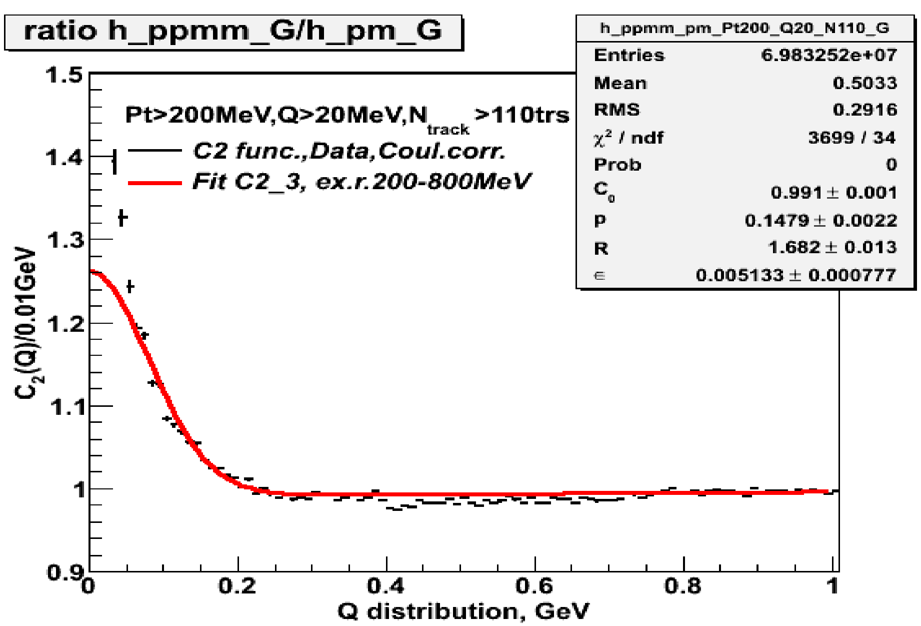
# 7 TeV data : C2 fit funs: C2_1,C2_2, C2_3, C2_4

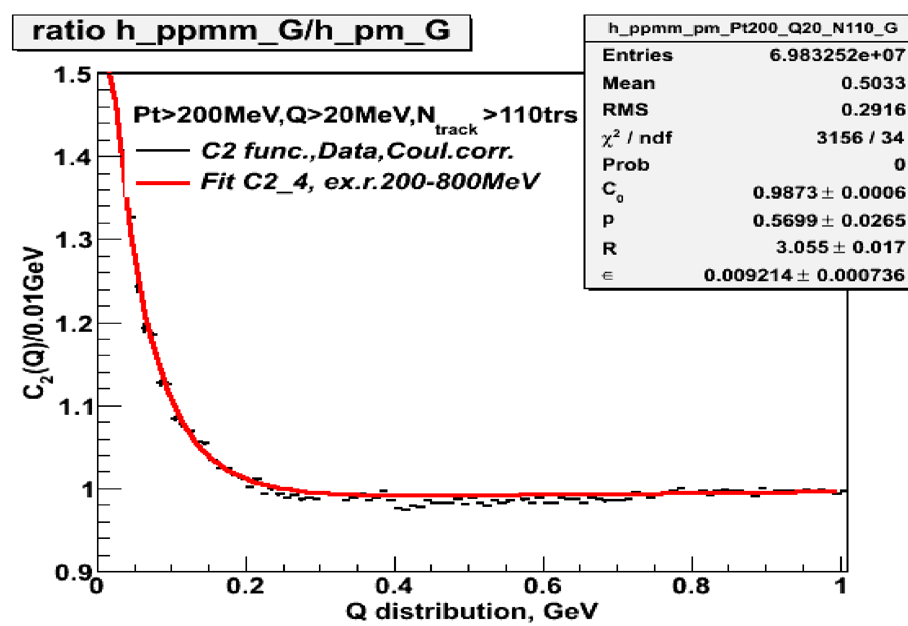
**Coulomb correction, Pt> 200 MeV, Q > 20 MeV, Ntracks > 110 tracks, excluded region (200-800MeV)**



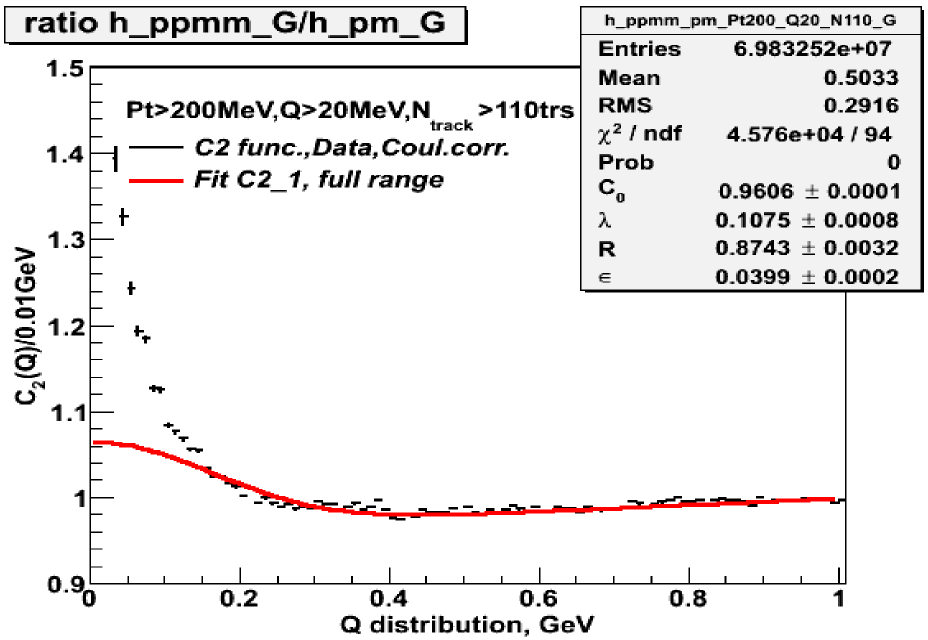

**Better fit!**

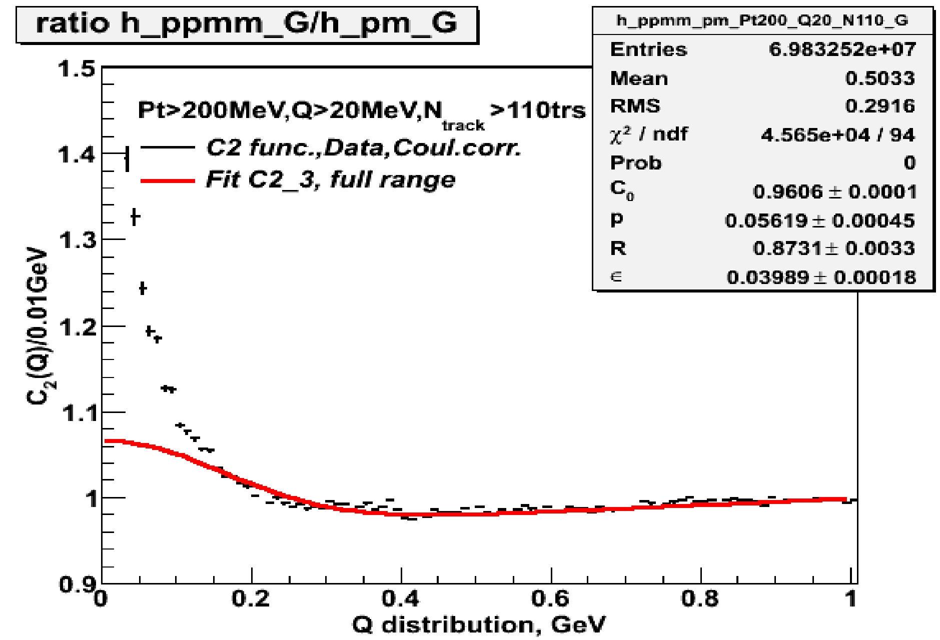


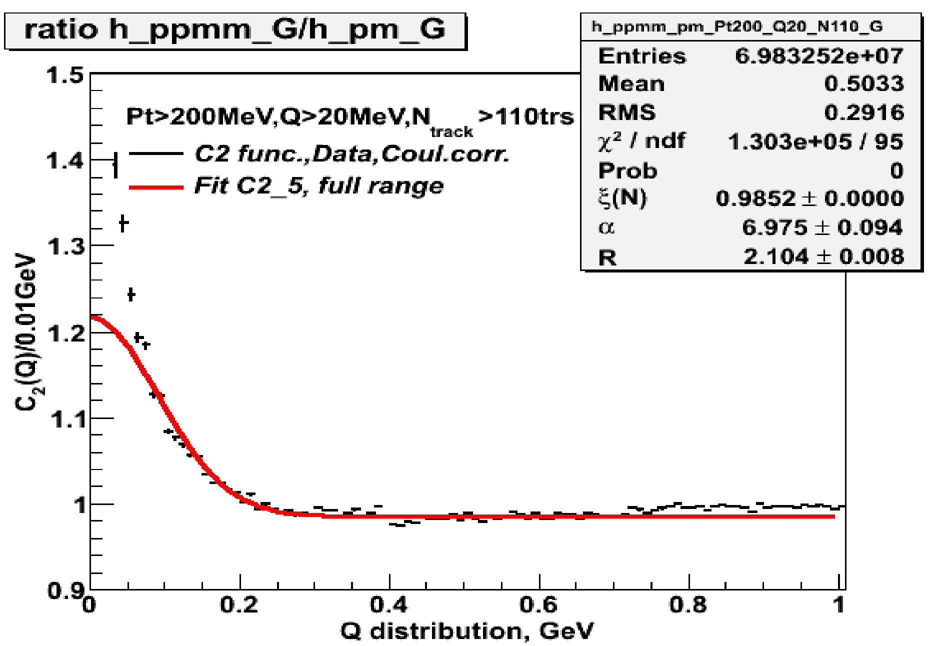



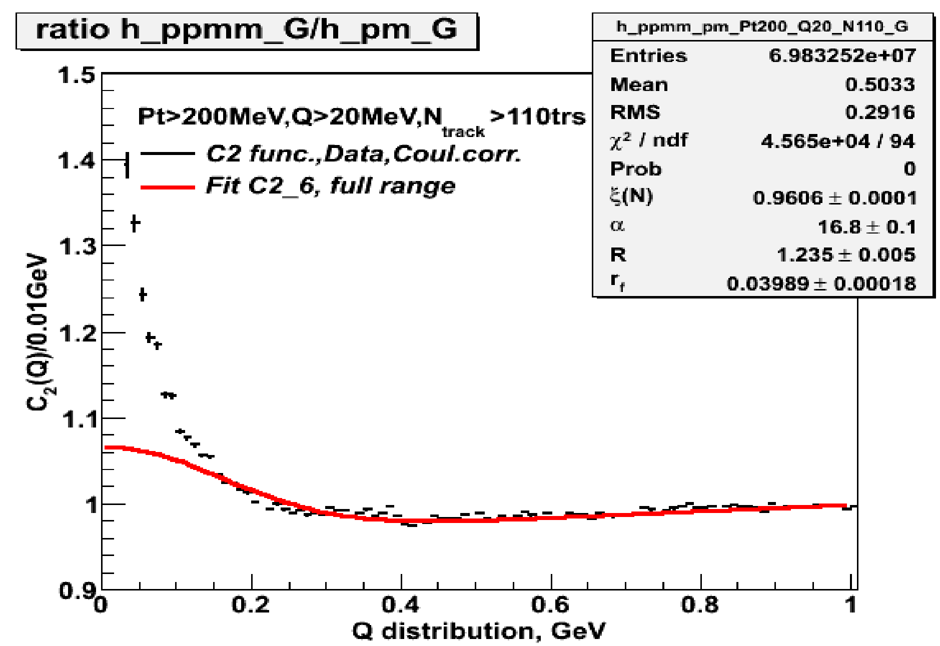
# 7 TeV data : C2 fit funs: C2_1,C2_3, C2_5, C2_6

## Coulomb corrections, Pt> 200 MeV, Q > 20 MeV, Ntracks > 110 tracks, full fitting interval



# 7 TeV data : C2 fit funs: C2_1,C2_3, C2_5, C2_6

**Coulomb correction, Pt> 200 MeV, Q > 20 MeV, Ntracks > 110 tracks, excluded region (200-800MeV)**