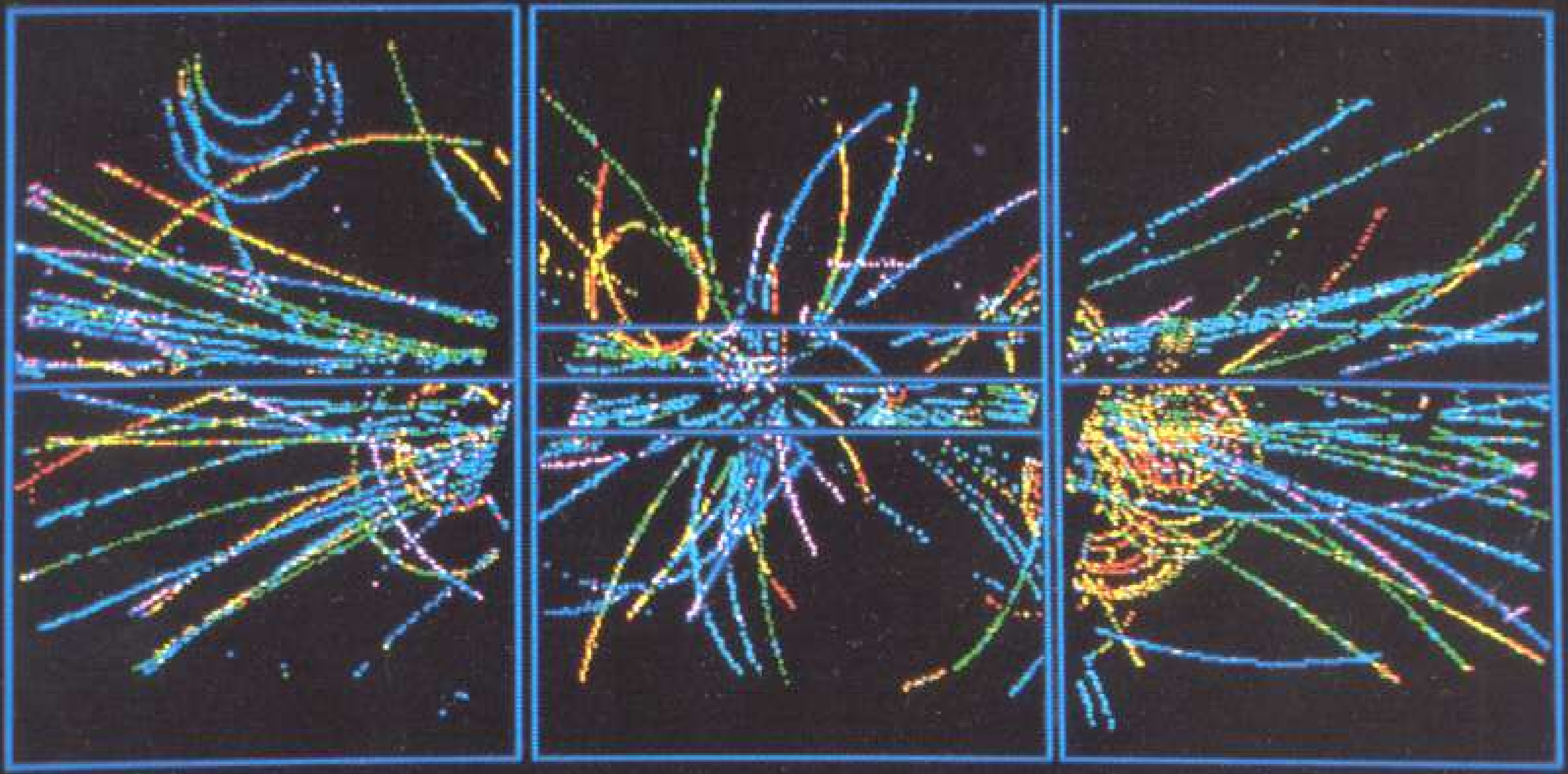
HBT Results from UA1
(and some comparisons)



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FJ October Inst for Maritime Technology, Simonstown

UA1: relic of the past; peek into the future?

- Hadronic physics as baseline for AA physics
- 630 GeV hadronic collisions:
  - energy dependence of everything
  - transverse jets AND longitudinal expansion
  - are the same models still valid? “New” or “different” physics?
- OUTLINE OF TALK:
  - cuts, corrections, normalisation issues
  - q0-q3
  - qlong-qtransverse: (slow cooking)
  - qout-qside-qlong (fast food)
- BOTTOM LINE: Current fits problematic due to strong peak. Discrepancy remains unexplained.

Cuts and characteristics

- $p\,\overline{p}$ at $\sqrt{s}=630$ GeV
- 2.45 million minimum-bias events
- Like-sign pions, some K contamination (no PID!)
- CUTS:
  - Single-particle: $|y|<3$ $p_t>0.15$ $-45^\circ\leq\phi\leq45^\circ,\ 135^\circ\leq\phi\leq225^\circ$
  - Pair cuts:
    - $Q^2=-(p_1-p_2)^2>0.0003$ GeV^2
    - Angle cuts ("alpha cut")
    - Ghost cut

$\langle n_{ch}\rangle=8.0$ after all cuts

- Corrections for Coulomb and ghost-cut overkill

Ghosts (split tracks) and merged tracks

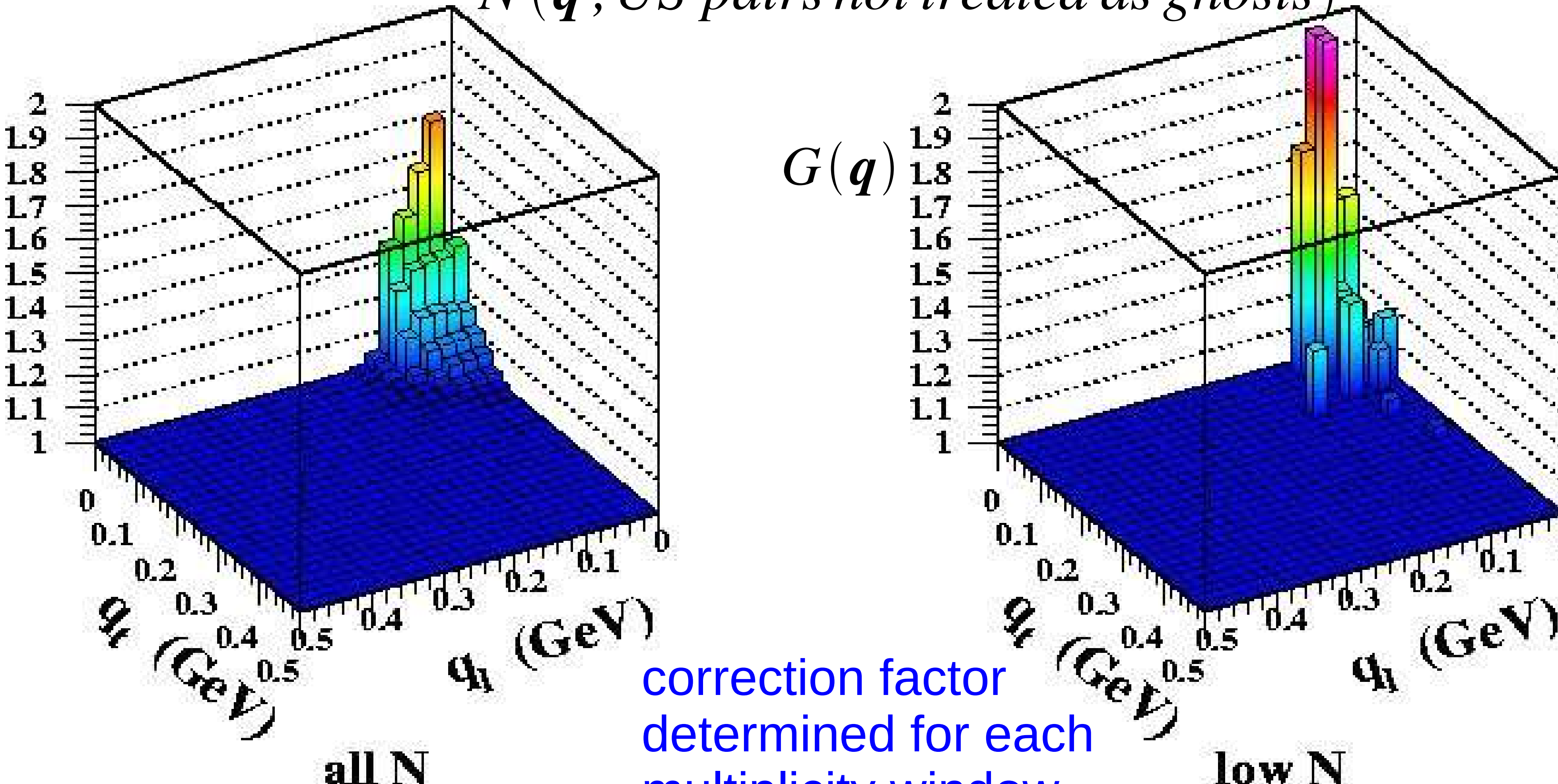
possible double counting of the same track (ghosts)

two overlapping real tracks may be counted as one

Correction factor for ghost cut overkill

Correct for removal of real LS pairs by the ghost cut by running US pairs through the same routines for a correction factor

$$G(\boldsymbol{q}) = \frac{N(\boldsymbol{q}, all\ US\ pairs)}{N(\boldsymbol{q}, US\ pairs\ not\ treated\ as\ ghosts)}$$



correction factor determined for each multiplicity window

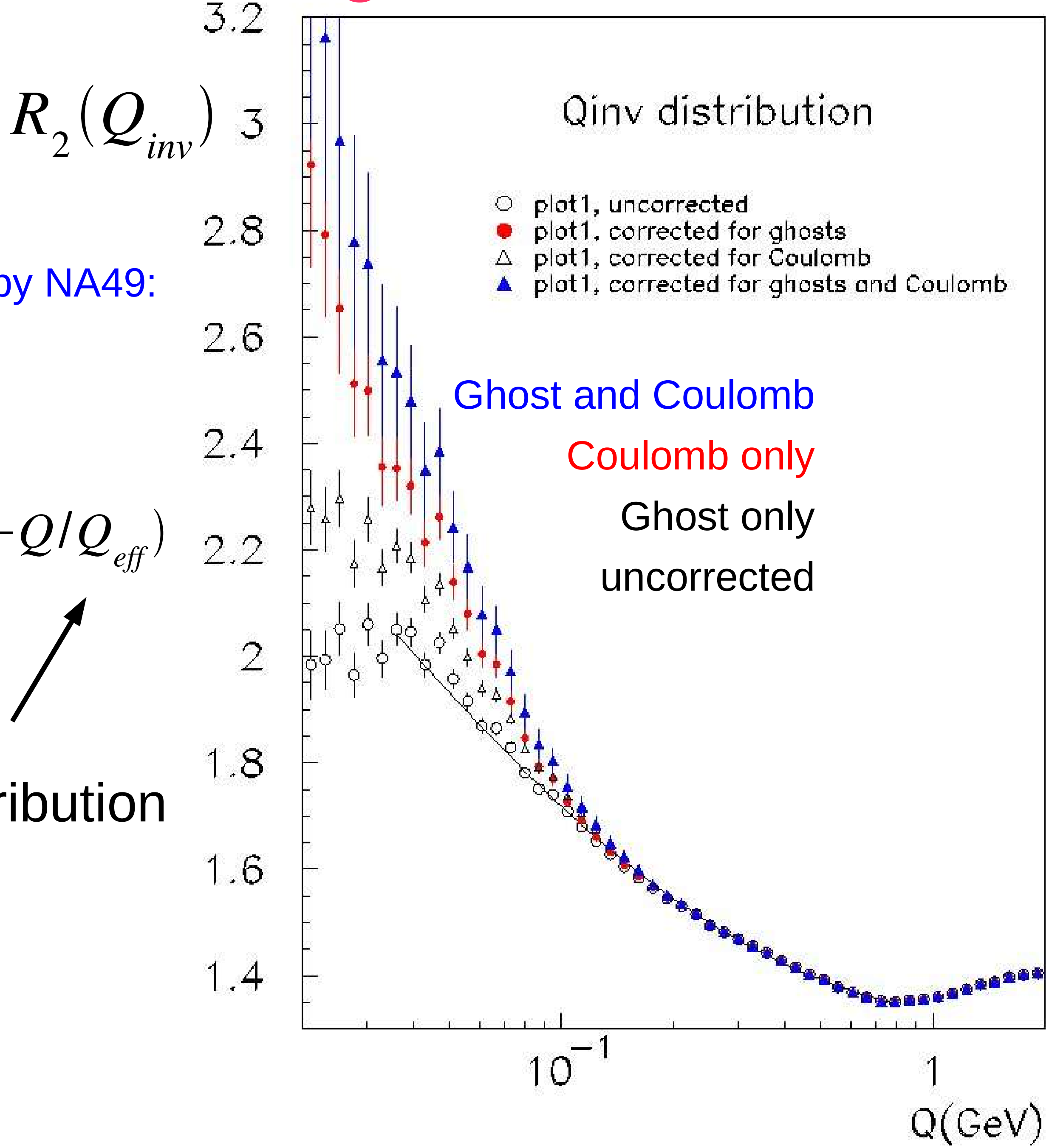
Effect of Coulomb and ghost-backcorrection

Effective correction as used by NA49:

Gamov

$$F(Q) = 1 + \left(G(Q) - 1\right) \exp\left(-Q/Q_{eff}\right)$$

parameter determined by unlike-sign pair distribution



Construction of reference sample

We use a sum over fixed-multiplicity subsamples:

$$R_2(\boldsymbol{q},\boldsymbol{K}) = \frac{\sum_N P_N \, \rho_2^{sib}(\boldsymbol{q},\boldsymbol{K};N)}{\sum_N P_N \, \rho_2^{ref}(\boldsymbol{q},\boldsymbol{K};N)}$$

where

$$\rho_2^{ref}(x_{1,}x_2;N) = \rho_2^{multinomial}(x_{1,}x_2;N)$$

is the second moment of the multinomial distribution

$$\rho_2^{multinomial}(x_{1,}x_2;N) = \frac{N-1}{N}\,\rho_1(x_1;N)\,\rho_1(x_2;N)$$

rather than the Poisson reference

$$\rho_2^{Poisson}(x_{1,}x_2) = \rho_1(x_1)\,\rho_1(x_2)$$

event-mixing using same-N track pool

In hadronic collisions, inclusion of the (N-1)/N factor is important!

NA22: (q0,q3)

$$q_0 = |E_1 - E_2|$$

$$q_3 = |\boldsymbol{q}|$$

$$Q_{inv}^2 = q_3^2 - q_0^2$$

IF

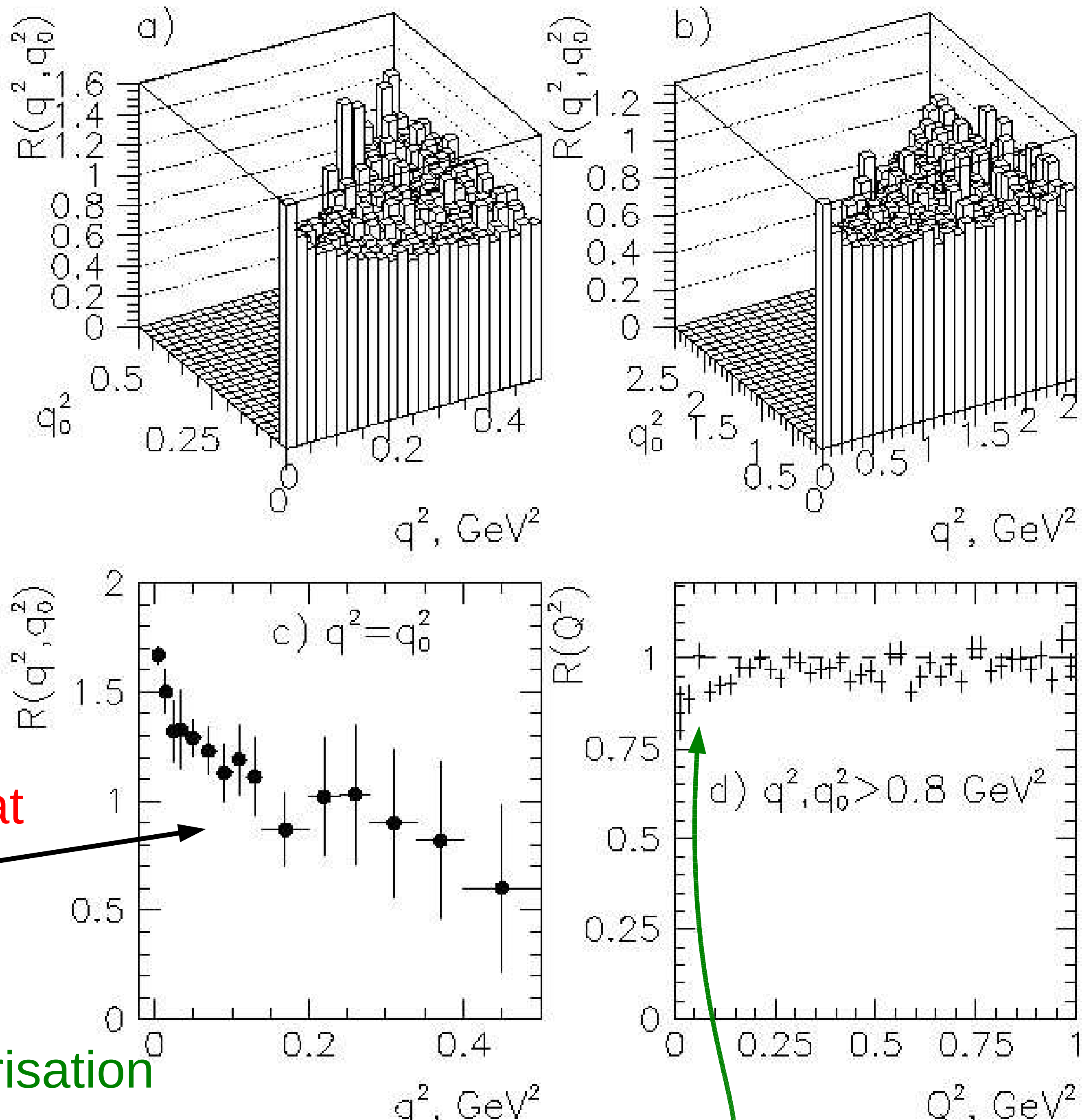
$$R_2(q_{0,} q_3) = R_2(Q_{inv}^2)$$

$$= 1 + \exp\left[-R^2 Q_{inv}^2\right]$$

$$= 1 + \exp\left[-R^2\left(q_3^2 - q_0^2\right)\right]$$

THEN this should be flat

(constant Q_{inv})



Lack of structure here

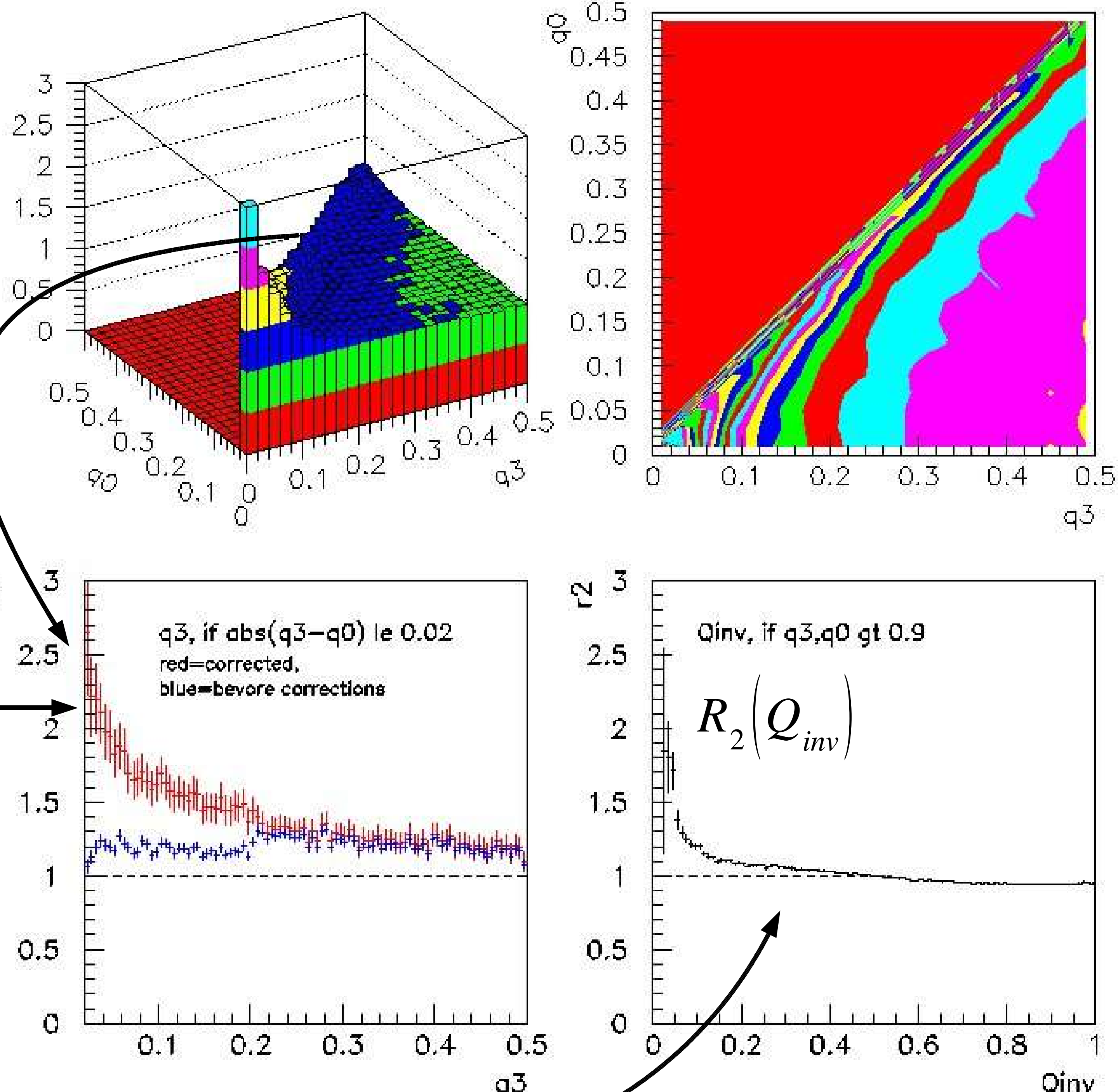
implies above parametrisation

is inappropriate for NA22

UA1: (q0,q3)

plot along
diagonal
= small Q_{inv}

R2 hence CANNOT
be described purely in
terms of Q_{inv}



HOWEVER, there IS
structure in R2(Qinv)
at large q3.

Simple parametrisations for R_2(ql,qt)

Generic structure: $$R_2 = \gamma \left[1 + \left| S_{12} \right|^2 \right]$$

Simple Gauss $$\left| S_{12} \right|^2 = \lambda \exp\left[-R_L^2 q_L^2 - R_T^2 q_T^2 \right]$$

Gauss with cross-term $$\left| S_{12} \right|^2 = \lambda \exp\left[-R_L^2 q_L^2 - R_T^2 q_T^2 - 2 R_{LT}^2 q_L q_T \right]$$

Exponential $$\left| S_{12} \right|^2 = \lambda \exp\left[-R_L q_L - R_T q_T \right]$$

Exponential w cross-term $$\left| S_{12} \right|^2 = \lambda \exp\left[-R_L q_L - R_T q_T - 2 R_{LT} \sqrt{q_L q_T} \right]$$

Power-law $$\left| S_{12} \right|^2 = \left(R_L q_L \right)^{-\alpha_L} \left(R_T q_T \right)^{-\alpha_T}$$

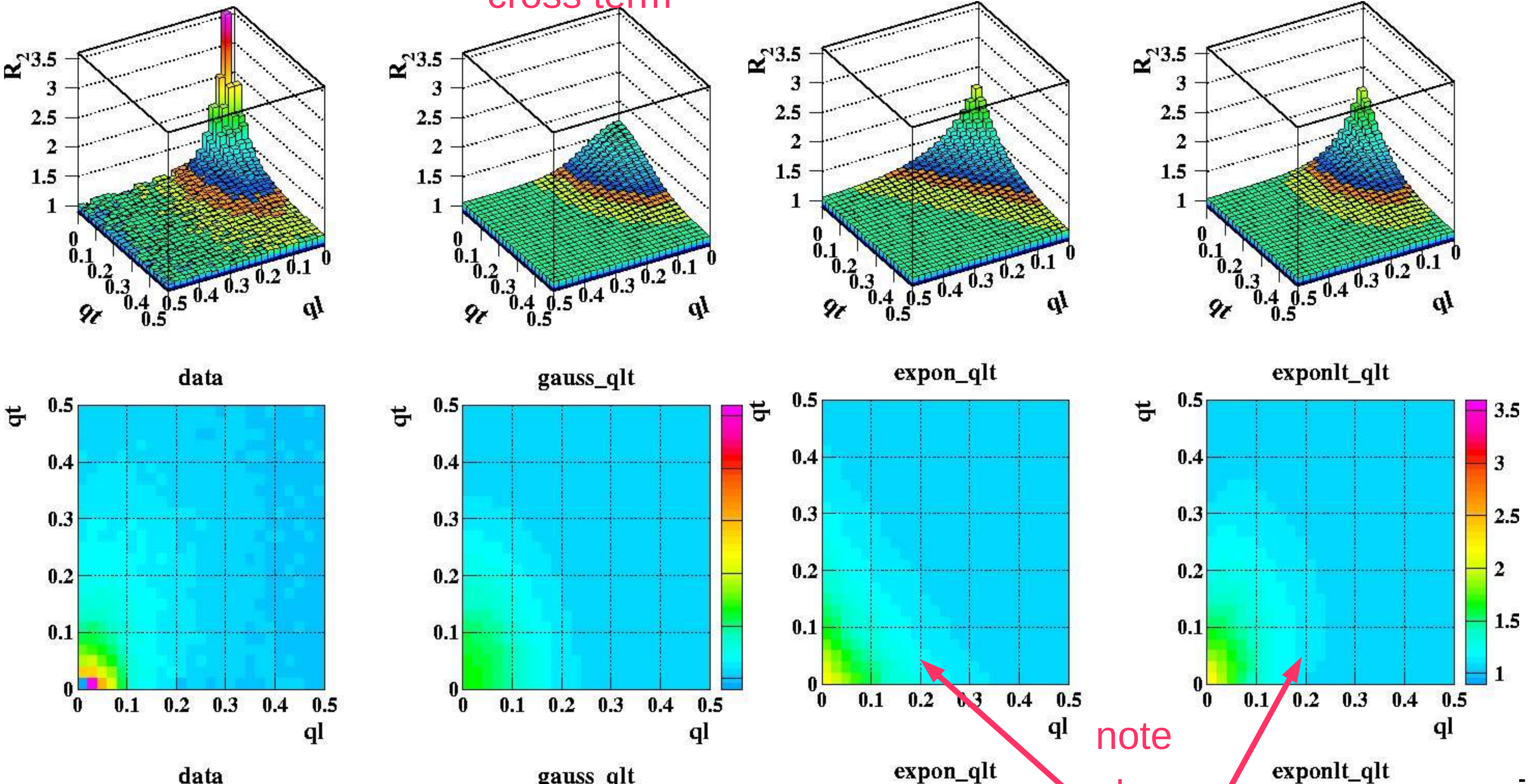
Simple fits of R2(ql,qt): peak heights and shapes

UA1 data

$\chi^2 / NDF = 9.3$
gauss with and without cross term

$\chi^2 / NDF = 7.3$
exponential

$\chi^2 / NDF = 4.7$
exponential with cross term

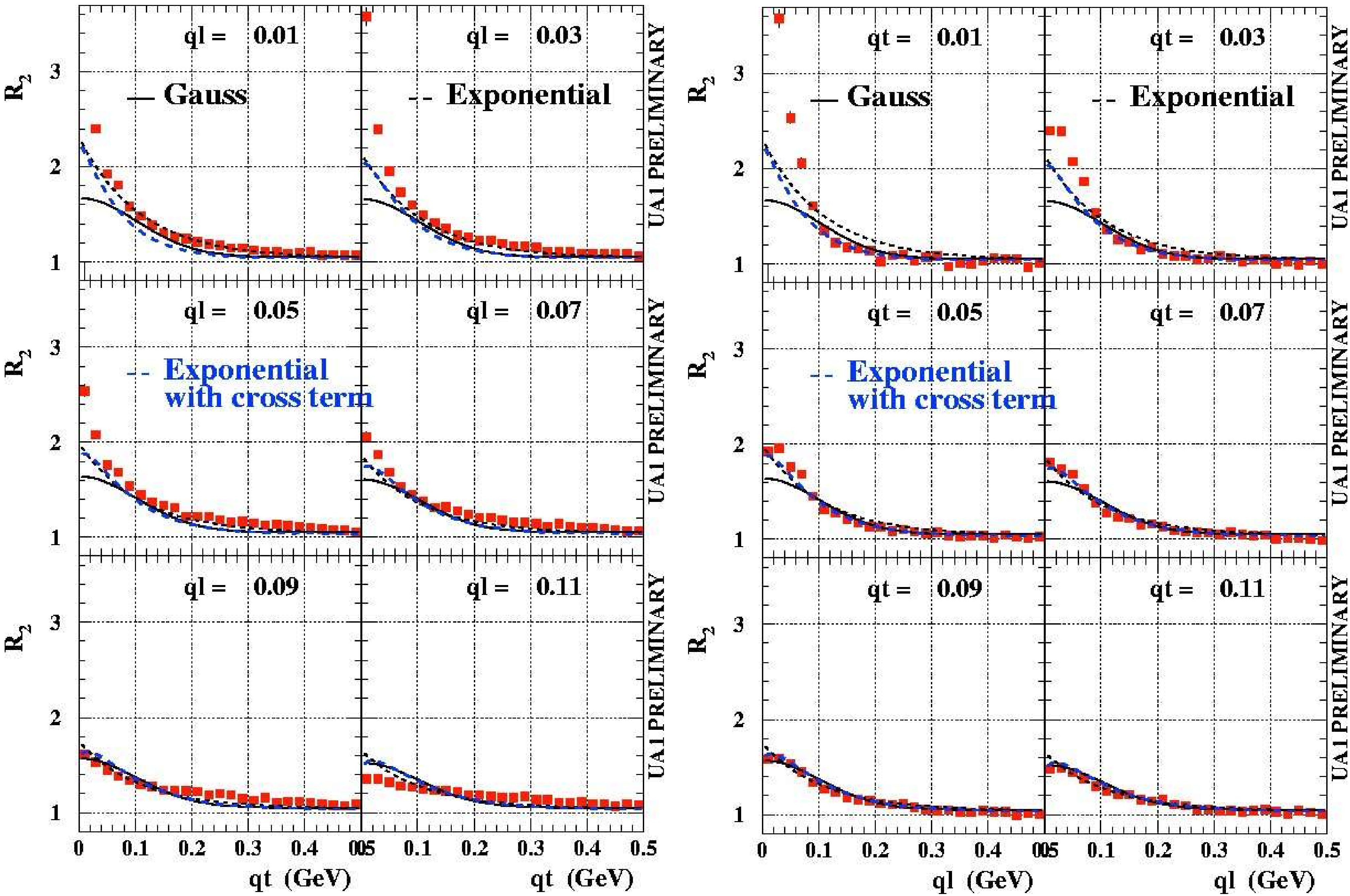


note shapes

Simple fits of R2(ql,qt)

fixed-ql slices

fixed-qt slices



Local χ^2

$$\chi^2 = \sum_{L,T} \chi^2_{L,T}$$

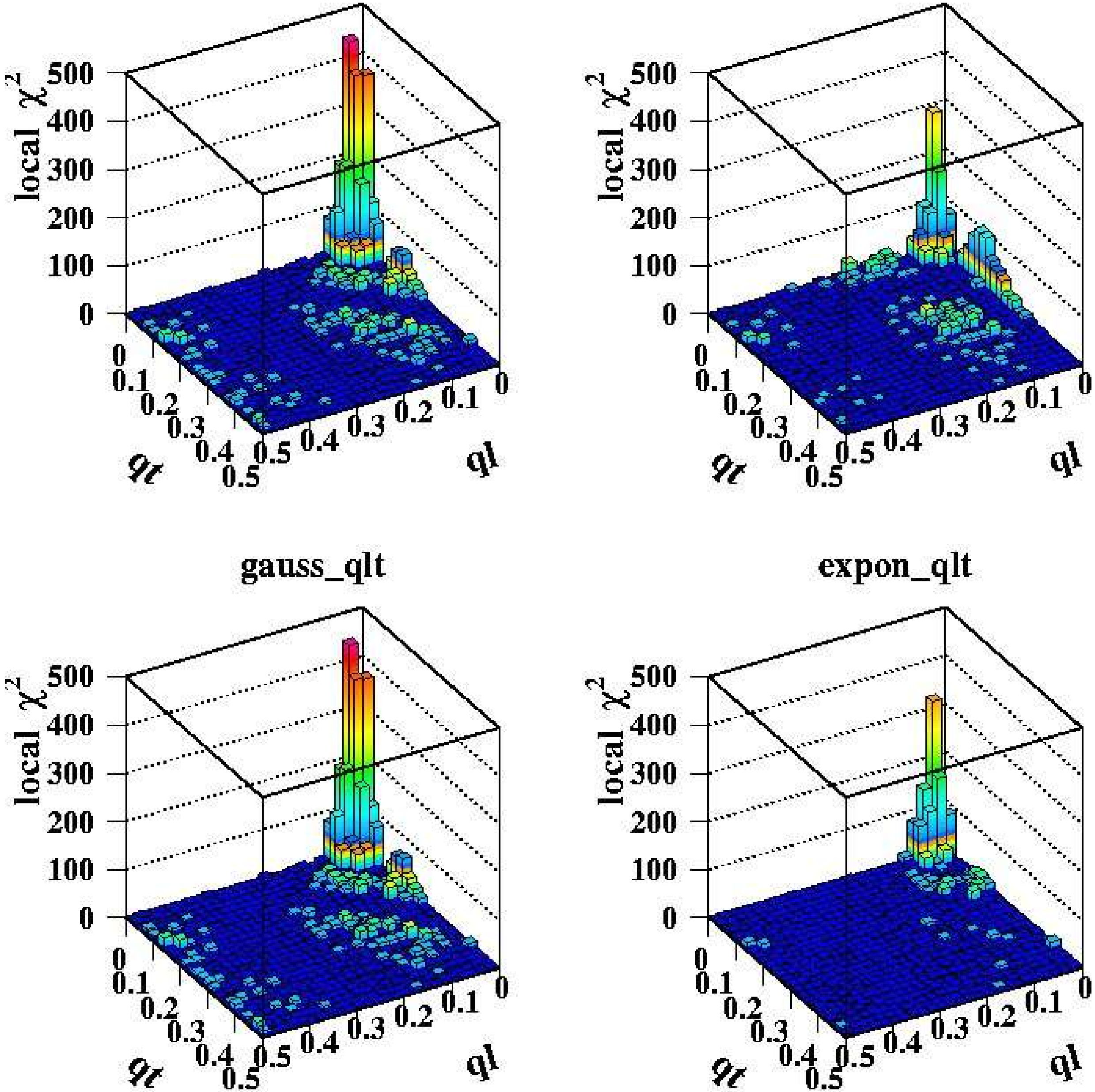
$$\chi^2_{L,T} = \frac{\left[R_2(q_L, q_T) - F(q_L, q_T)\right]^2}{\sigma^2(q_L, q_T)}$$

data

fit function

gauss

exponential

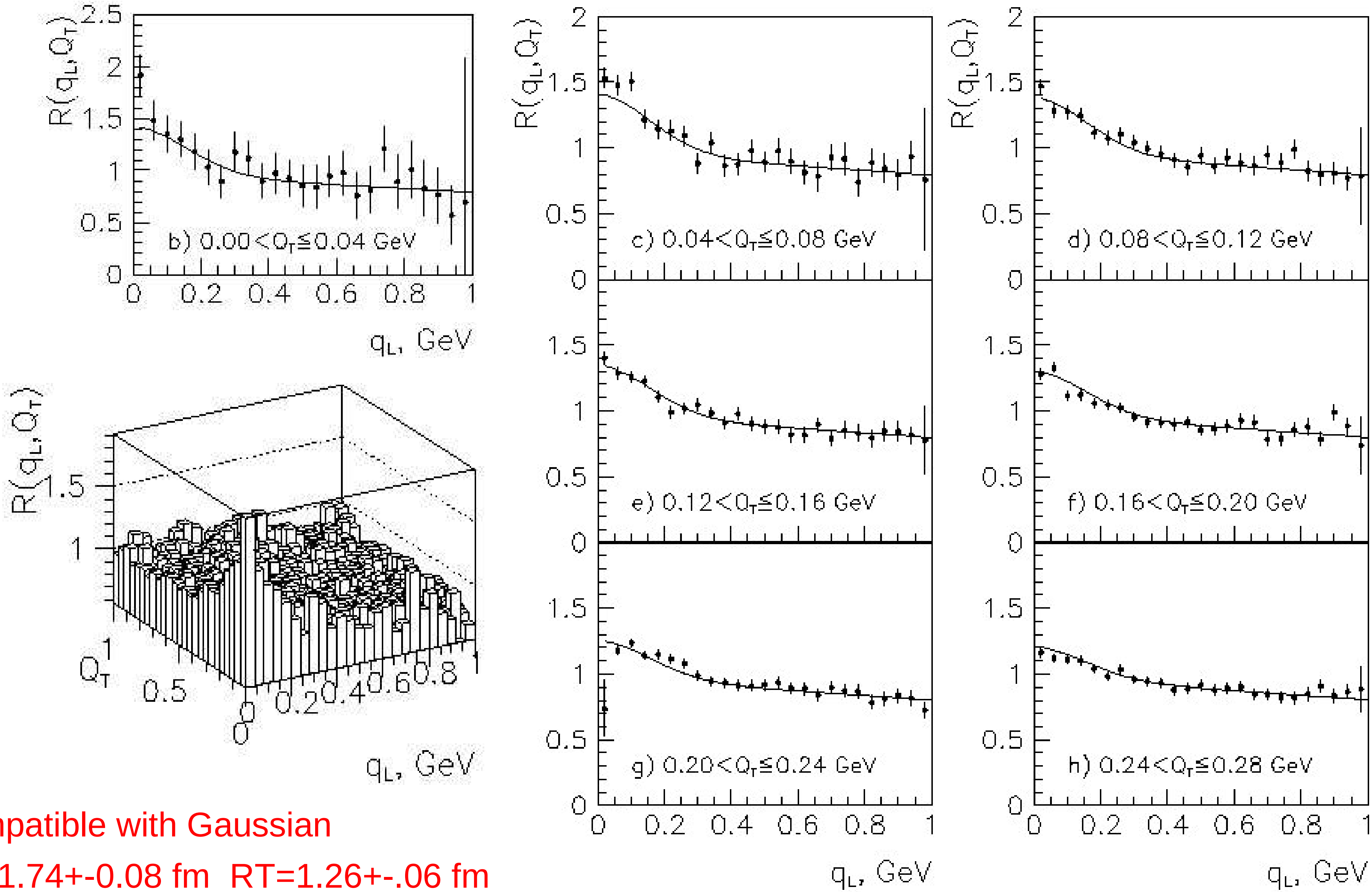


gauss with cross term

exponential with cross term

R2(ql,qt) by NA22

ZPC 71,405 (1996)



Compatible with Gaussian

RL=1.74+-0.08 fm RT=1.26+-.06 fm

CHISQ/NDF = 0.97

Edgeworth and Levy-stable parametrisations

Generic structure: $$R_2 = \gamma \left[1 + \left| S_{12} \right|^2 \right]$$

must be symmetric in q_L, q_T

Edgeworth

$$\left| S_{12}{}^2 \right| = \lambda \exp\left(-\sum_i R_i^2 q_i^2 \right) \prod_i \left(1 + \frac{\kappa_{4i}}{24} H_4(x_i) \right)$$

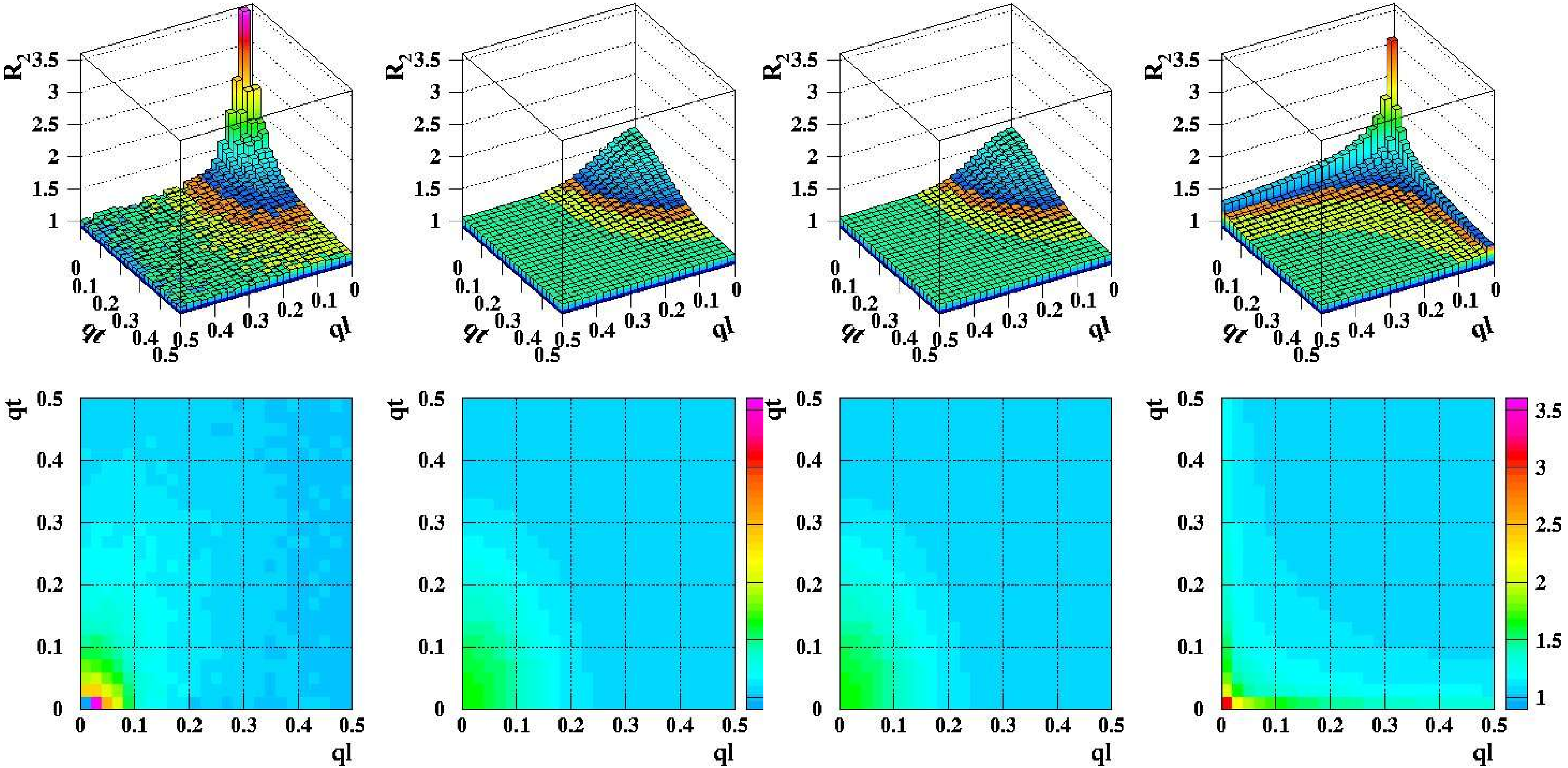
$$x_i = \sqrt{2}\, R_i\, q_i \quad i = L, T$$

Levy-stable

$$\left| S_{12}{}^2 \right| = \lambda \exp\left[-\left(R_L^2 q_L^2 + R_T^2 q_T^2 \right)^{\alpha/2} \right]$$

Back to UA1: Edgeworth and power-law fits of R2(ql,qt)

UA1 data | gauss | Edgeworth with κ_4 | power-law in both ql and qt



Levy for R2(ql,qt): unstable fits

8 out of 18 initial parameter value sets converged:

Gamma	Lambda	Alpha	Rlong	Rtrans	CHISQ
0.9731	50.97	0.2298	1760	1222	3.10
0.9721	56.69	0.2242	2290	1590	3.10
0.9721	56.23	0.2246	2244	1558	3.10
0.9700	71.54	0.2130	4113	2857	3.10
0.9716	60.06	0.2214	2641	1835	3.10
0.9728	52.02	0.2287	1852	1286	3.10
0.9714	60.99	0.2206	2748	1908	3.10
0.9733	49.39	0.2314	1629	1131	3.10

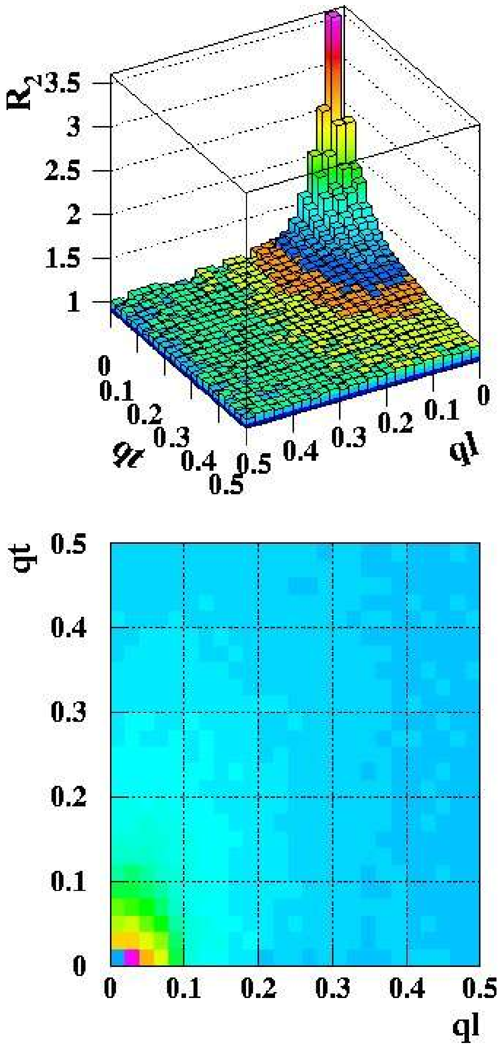
AFTER LEAVING OUT A SECOND POINT:

11 out of 18 initial parameter value sets converged:

Gamma	Lambda	Alpha	Rlong	Rtrans	CHISQ
1.9700	48.90	0.2272	1833	1258	2.78
0.9711	43.79	0.2332	1392	955	2.78
3.8255	-0.75	-1.0977	-10	-7	2.78
0.9710	44.32	0.2325	1435	985	2.78
0.9628	109.20	0.1909	14964	10275	2.78
2.8633	-0.67	-1.2269	-6	4	2.78
0.9724	38.81	0.2401	1036	711	2.78
0.9705	46.40	0.2300	1609	1104	2.78
0.9713	43.09	0.2341	1337	918	2.78
0.9717	41.31	0.2364	1208	829	2.78
0.9701	48.52	0.2276	1795	1232	2.78

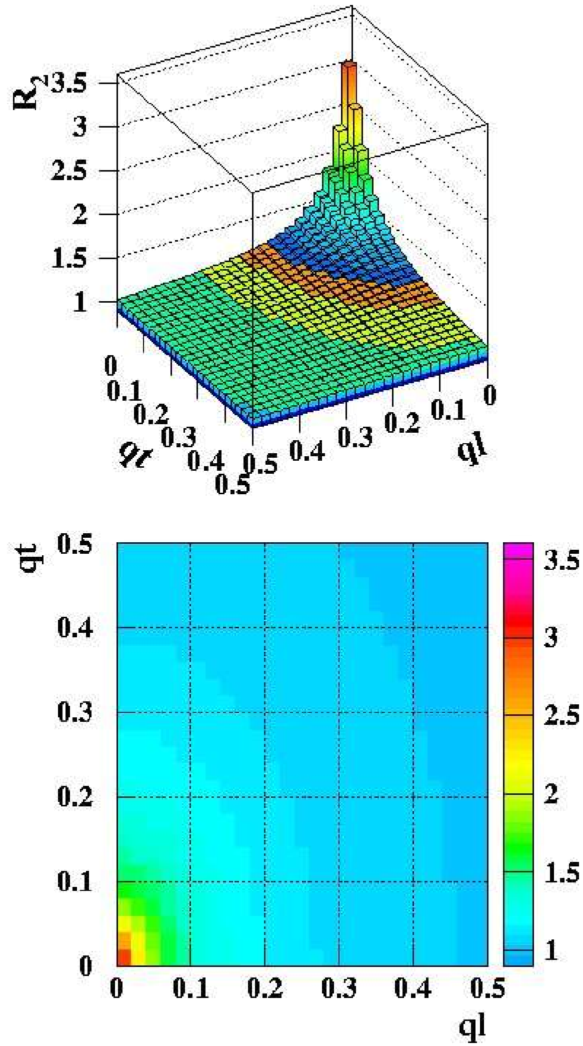
Levy for $R_2(q_L,q_T)$: representative plots

UA1 data

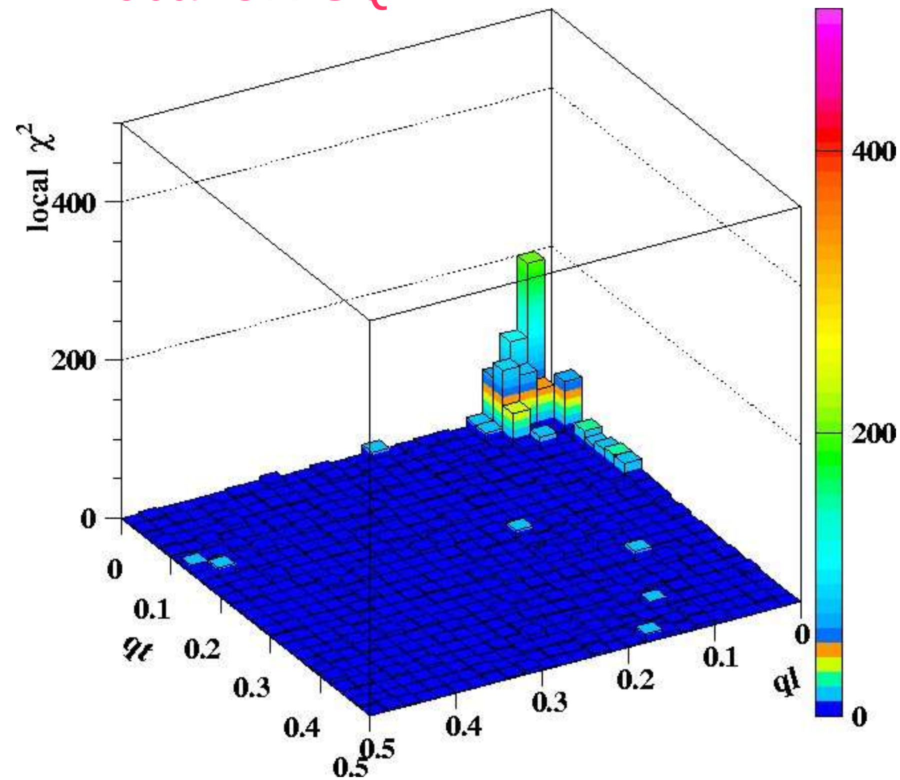


Levy best fit

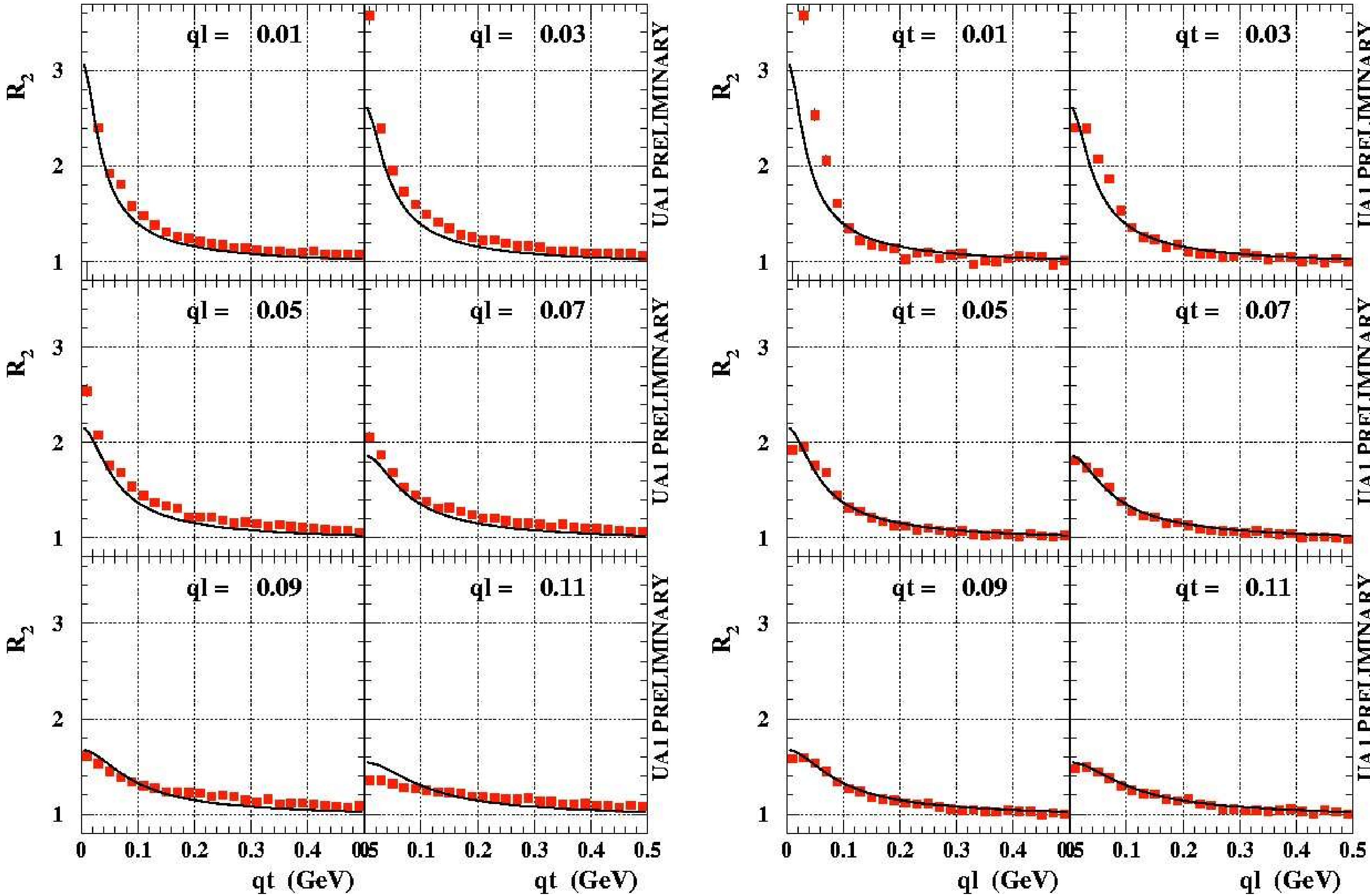
(one of many)



local CHISQ



Levy in (ql,qt): representative plots



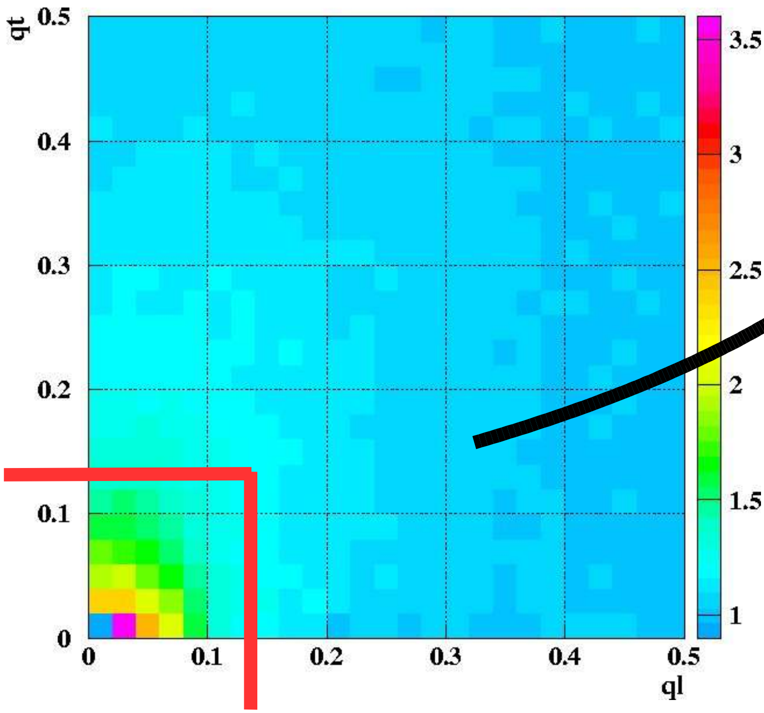
Eggers WPCF05

Alternative approach: **impose** two scales

Given the strong peak, we simply impose two scales in the form of a double Gaussian:

$$R_2(q_L, q_T) = \gamma\left[1 + \lambda_H \exp\left(-R_{LH}^2 q_L^2 - R_{TH}^2 q_T^2\right) + \lambda_C \exp\left(-R_{LC}^2 q_L^2 - R_{TC}^2 q_T^2\right)\right]$$

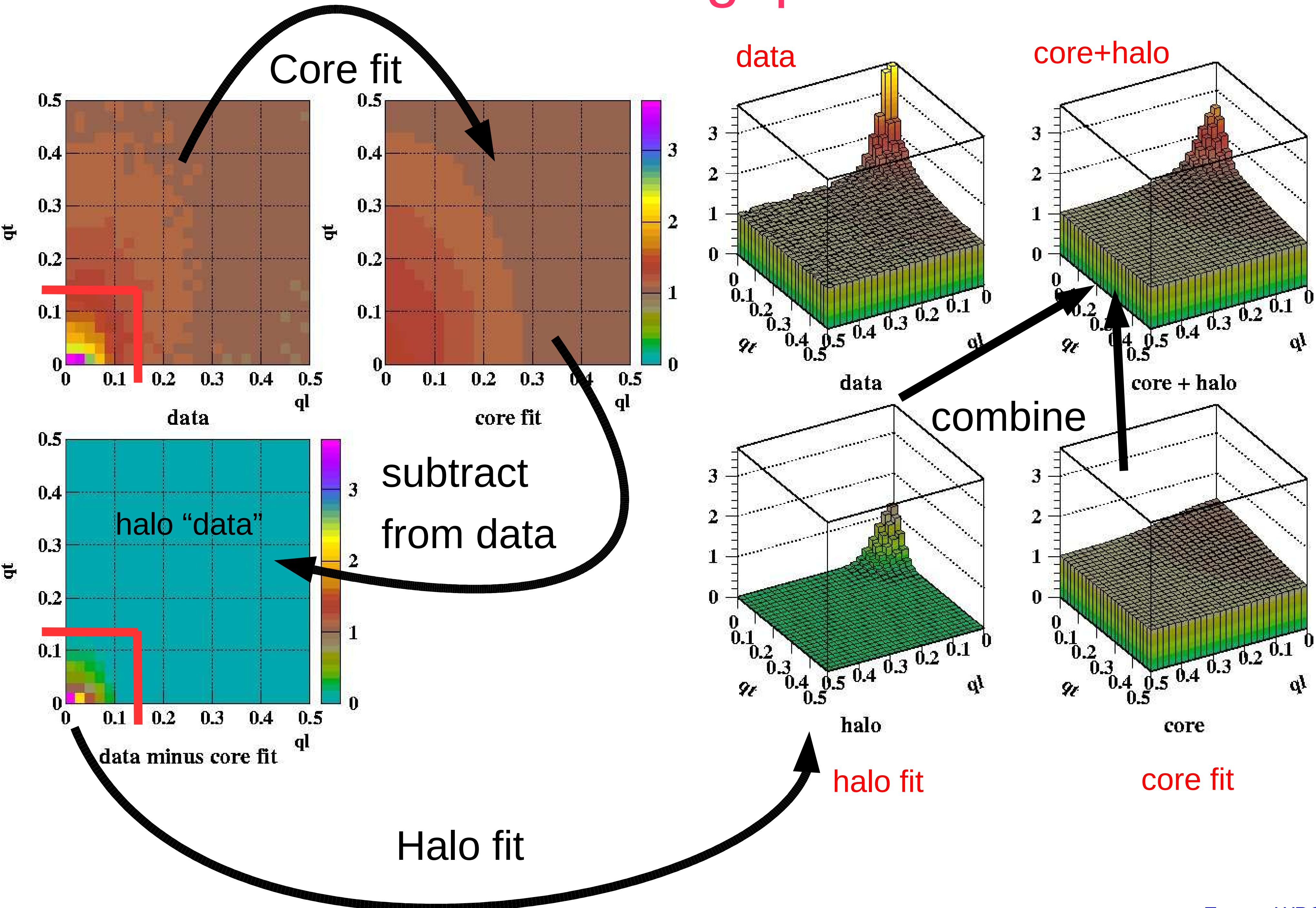
“HALO”



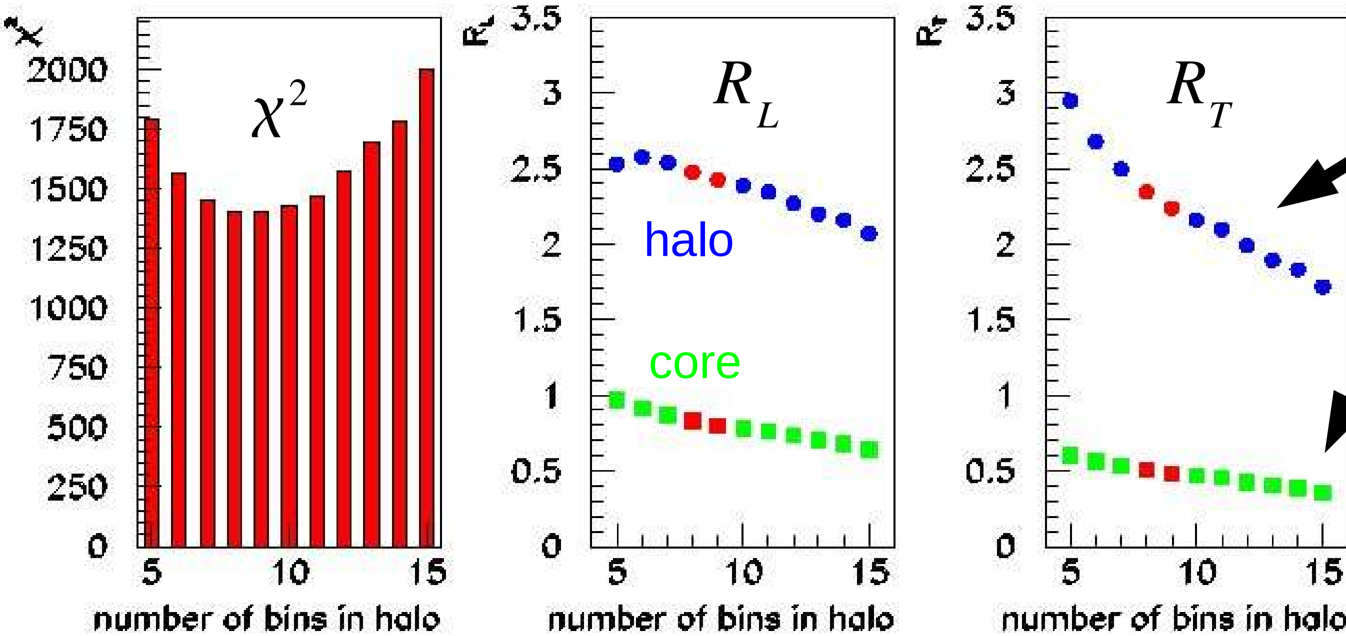
“CORE”

Separate “core” and “halo” by hard cut

Two-scale fitting: procedure



Two scale fits: dependence on cut



good separation of scales

$R_{LC} = 0.82 \pm 0.02$

$R_{TC} = 0.49 \pm 0.02$

$R_{LH} = 2.45 \pm 0.03$

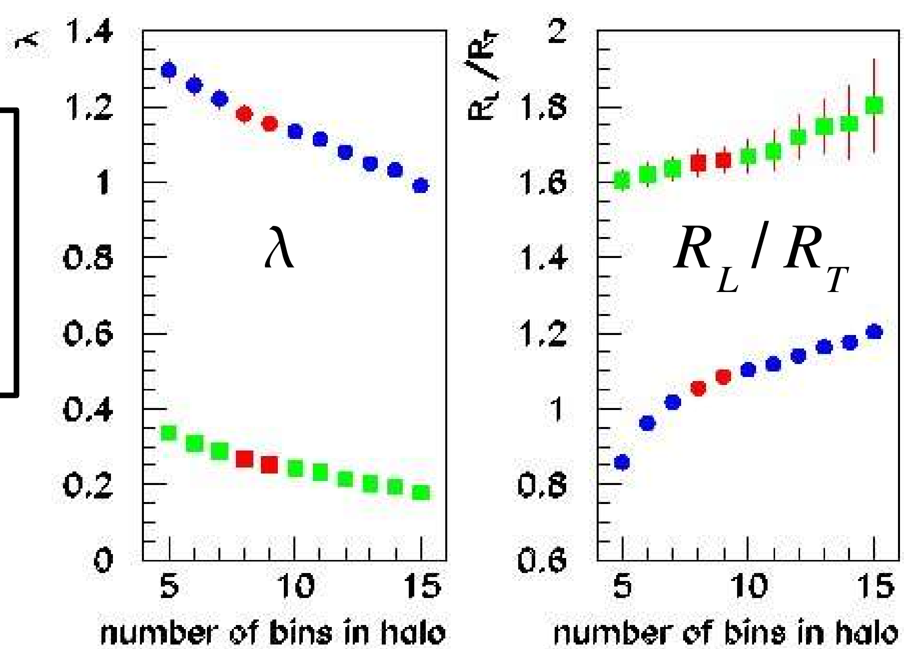
$R_{TH} = 2.29 \pm 0.05$

$R_{LC} / R_{TC} = 1.67$

$R_{LH} / R_{TH} = 1.07$

$\chi^2 / NDF = 2.28$

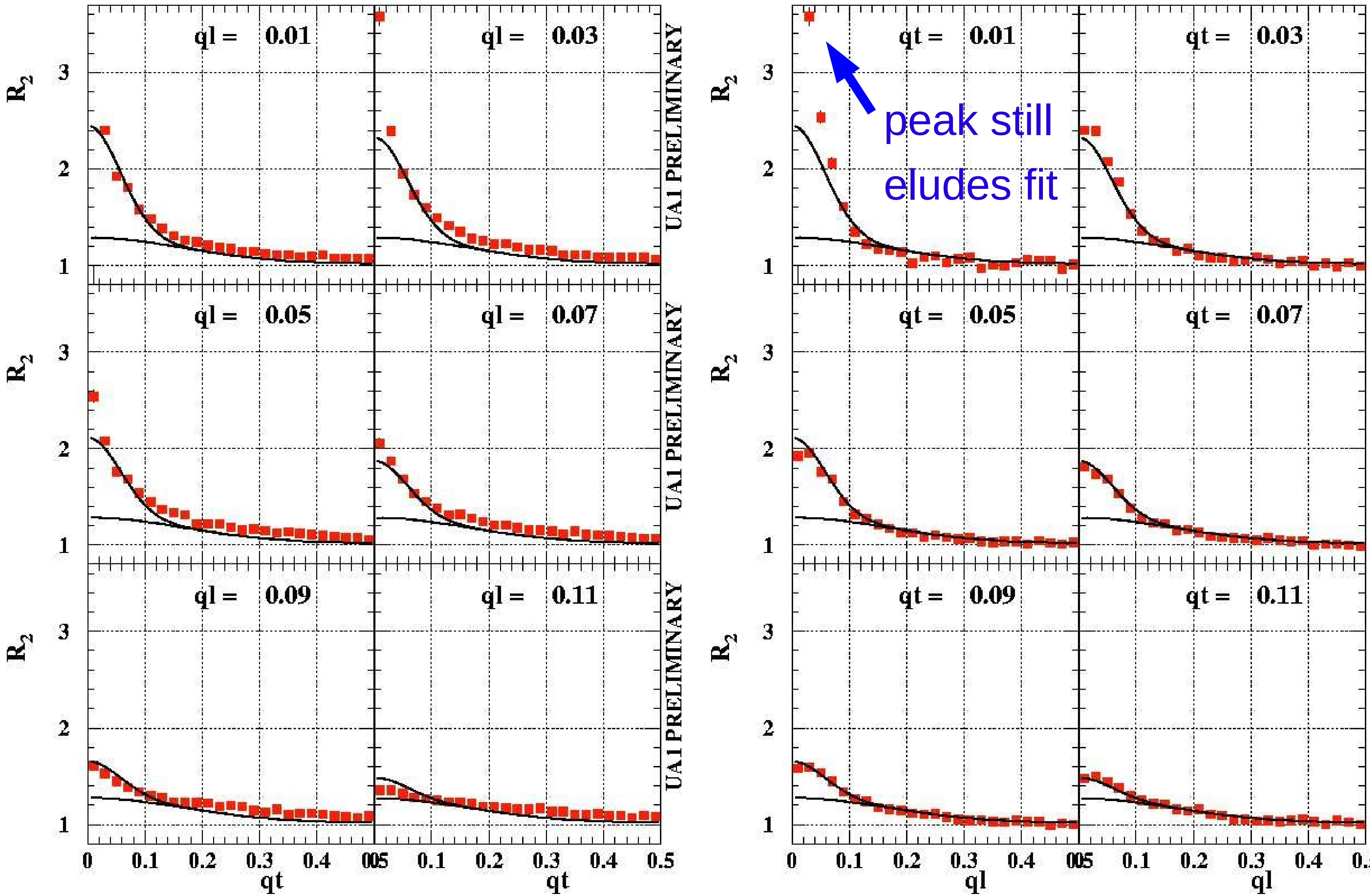
Best chisq for cut at 140-160 MeV



Core clearly prolate, Halo approx spherical

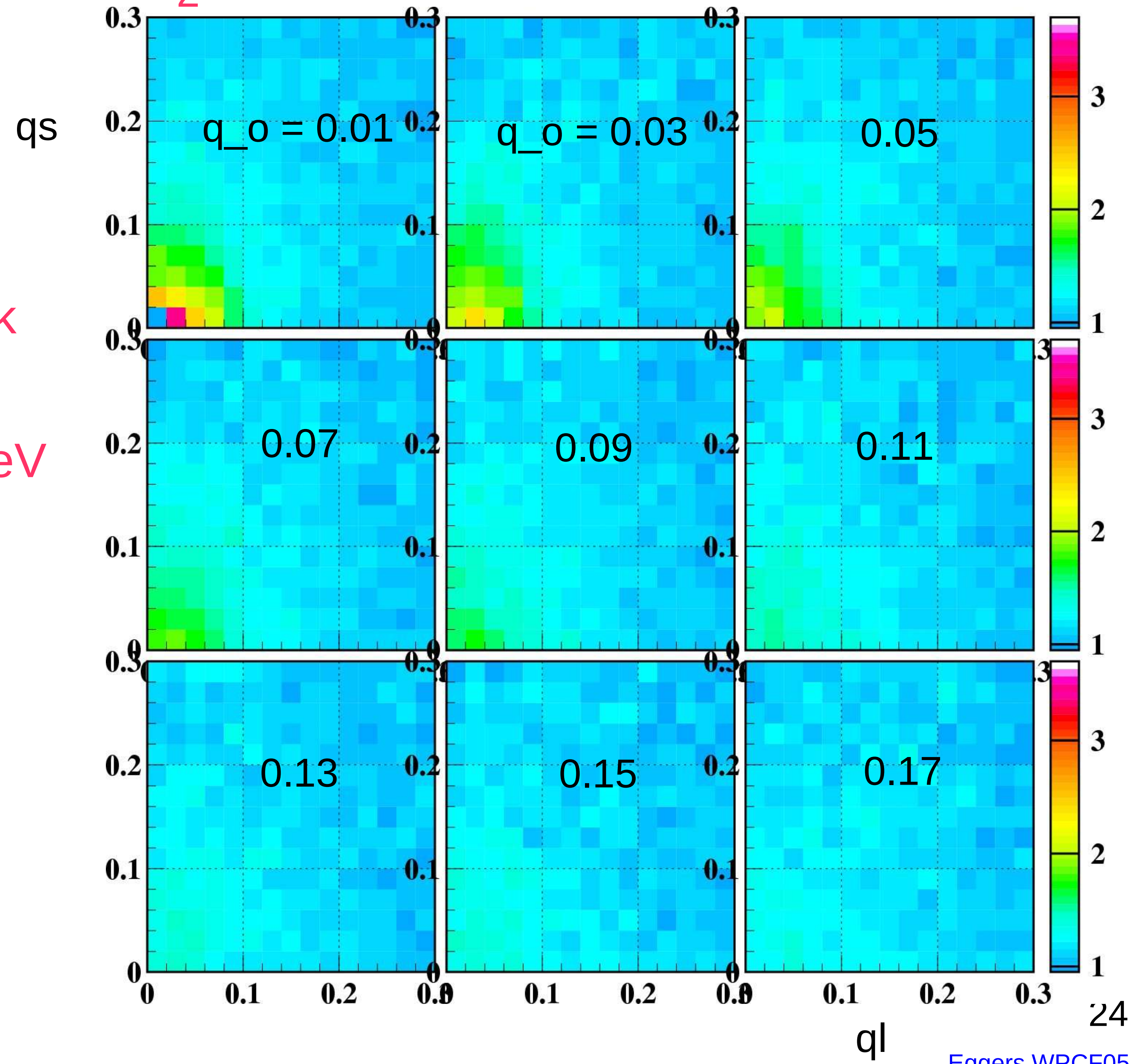
Two-scale fits: slices

8x8 cut   2/NDF = 2.28



UA1 R_2(qo, qs, ql) data

The sharp peak is confined to the first 100 MeV in 3D also.

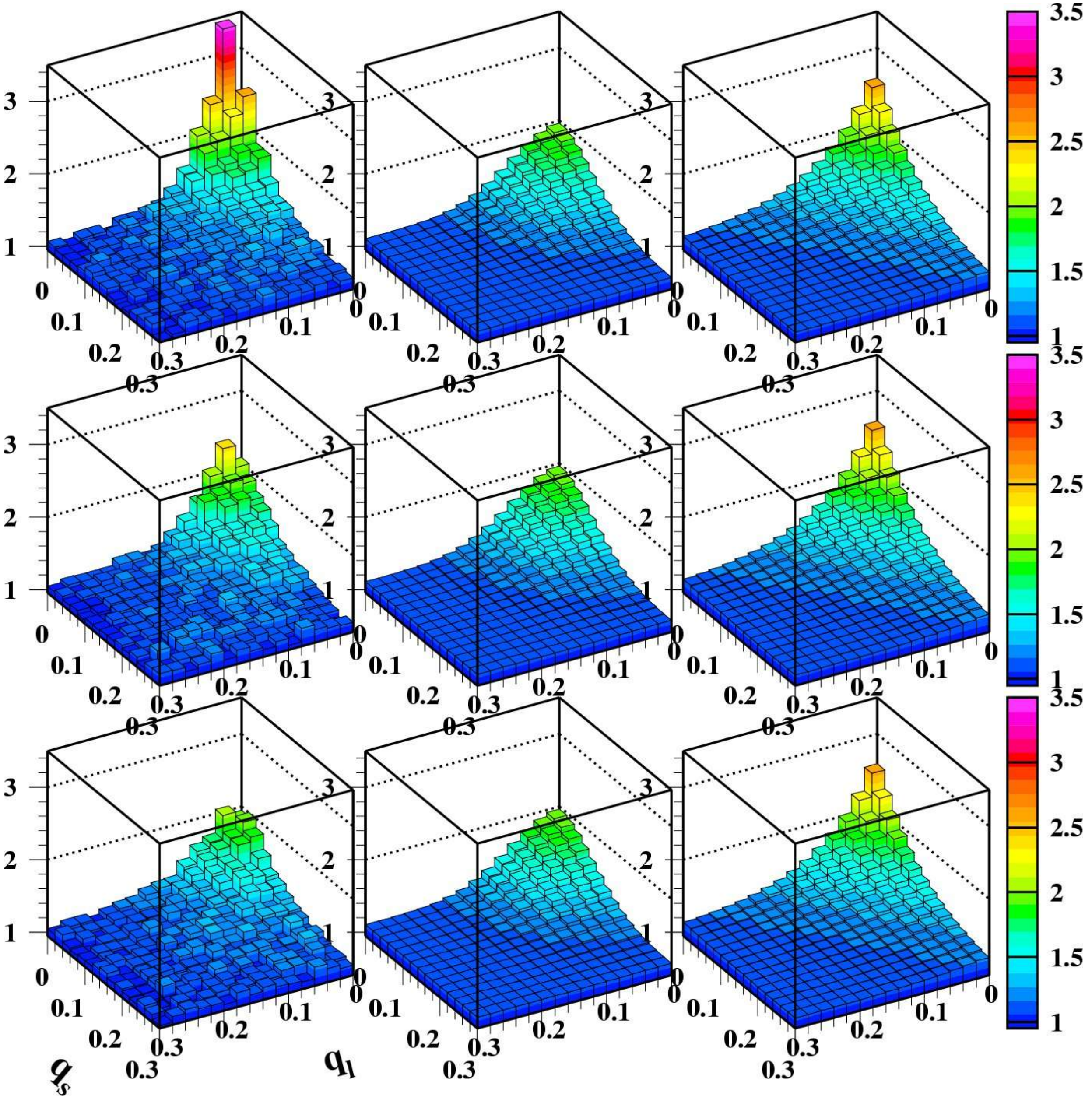


R_2(qo, qs, ql): simple fits again don't work

$q_o = 0.01$

$q_o = 0.03$

$q_o = 0.05$



data gauss exponential

gauss $\chi^2 / NDF = 9.3$

exponential $\chi^2 / NDF = 7.3$

3D Edgeworth and Levy-stable distributions

For Bertsch-Pratt, try:

Edgeworth expansion for symmetric distributions:

$$R_2(\boldsymbol{q}) = \gamma\left[1 + \lambda \exp\left(-\sum_i R_i^2 q_i^2\right) \prod_i \left(1 + \frac{\kappa_{4i}}{24} H_4(x_i)\right)\right]$$

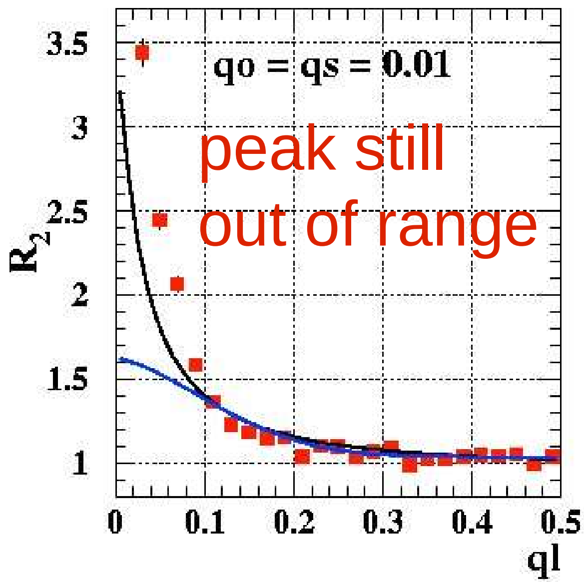
$$x_i = \sqrt{2}\, R_i q_i \quad i = o, s, l$$

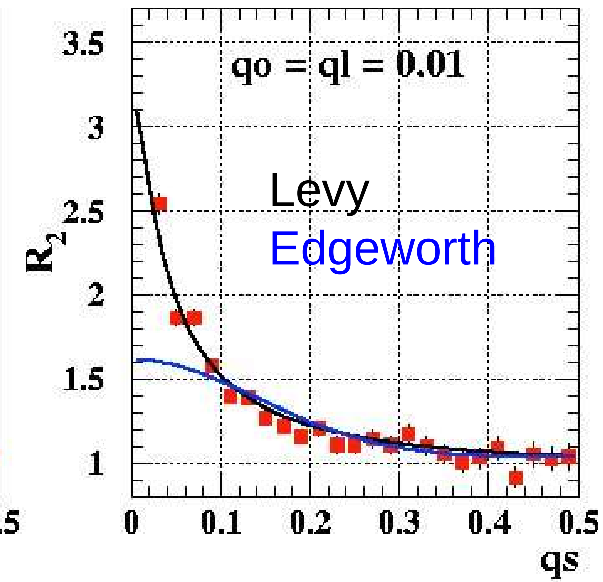
Levy distribution with single exponent:

$$R_2(\boldsymbol{q}) = \gamma\left[1 + \lambda \exp\left(-\left(R_o^2 q_o^2 + R_s^2 q_s^2 + R_l^2 q_l^2\right)^{\alpha/2}\right)\right]$$

Result: Again, fits look OK but there is substantial parameter redundancy: no single set of best-fit values.

Edgeworth and Levy: representative plots on the axes



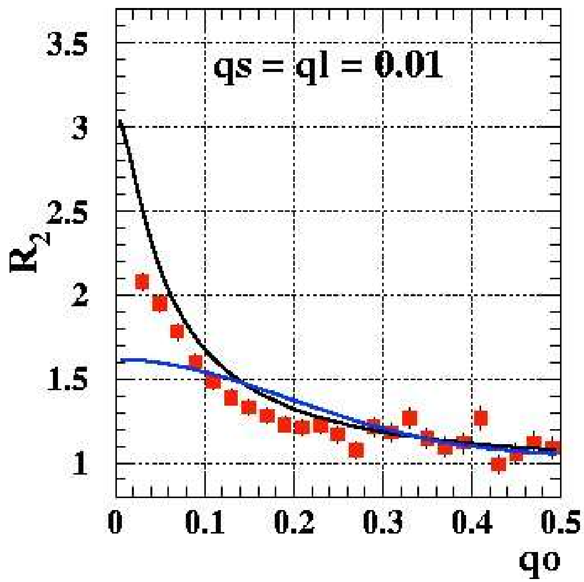


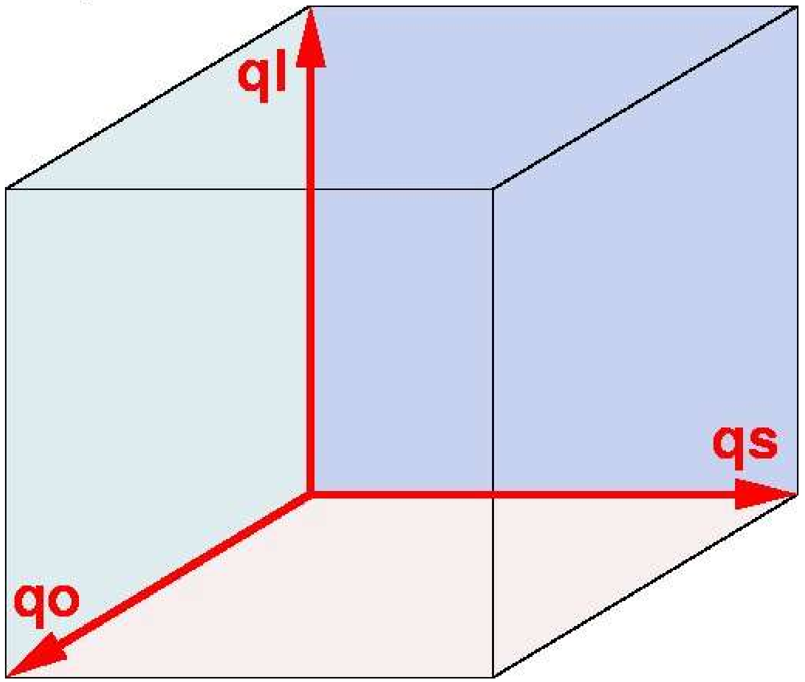
Levy

$\chi^2 / NDF = 1.09$

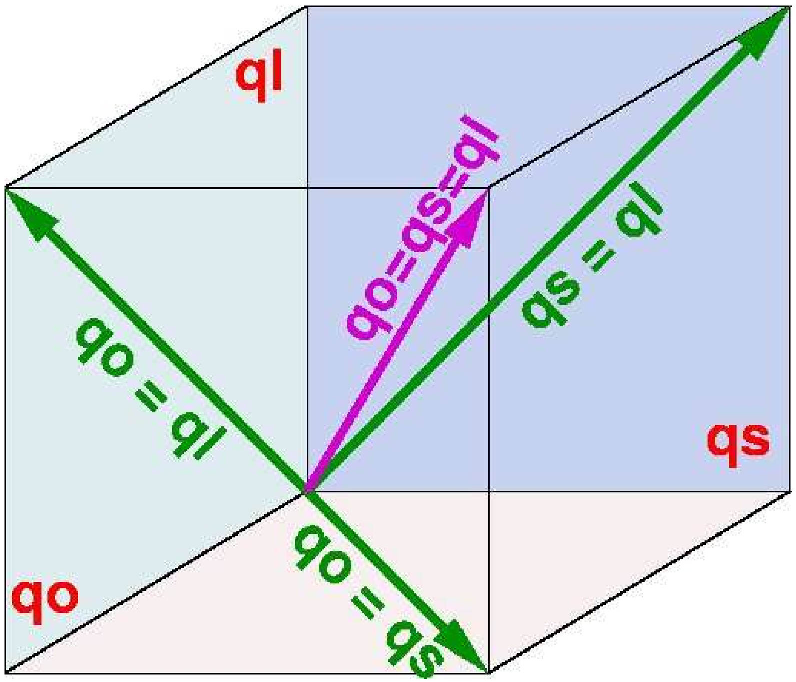
Edgeworth

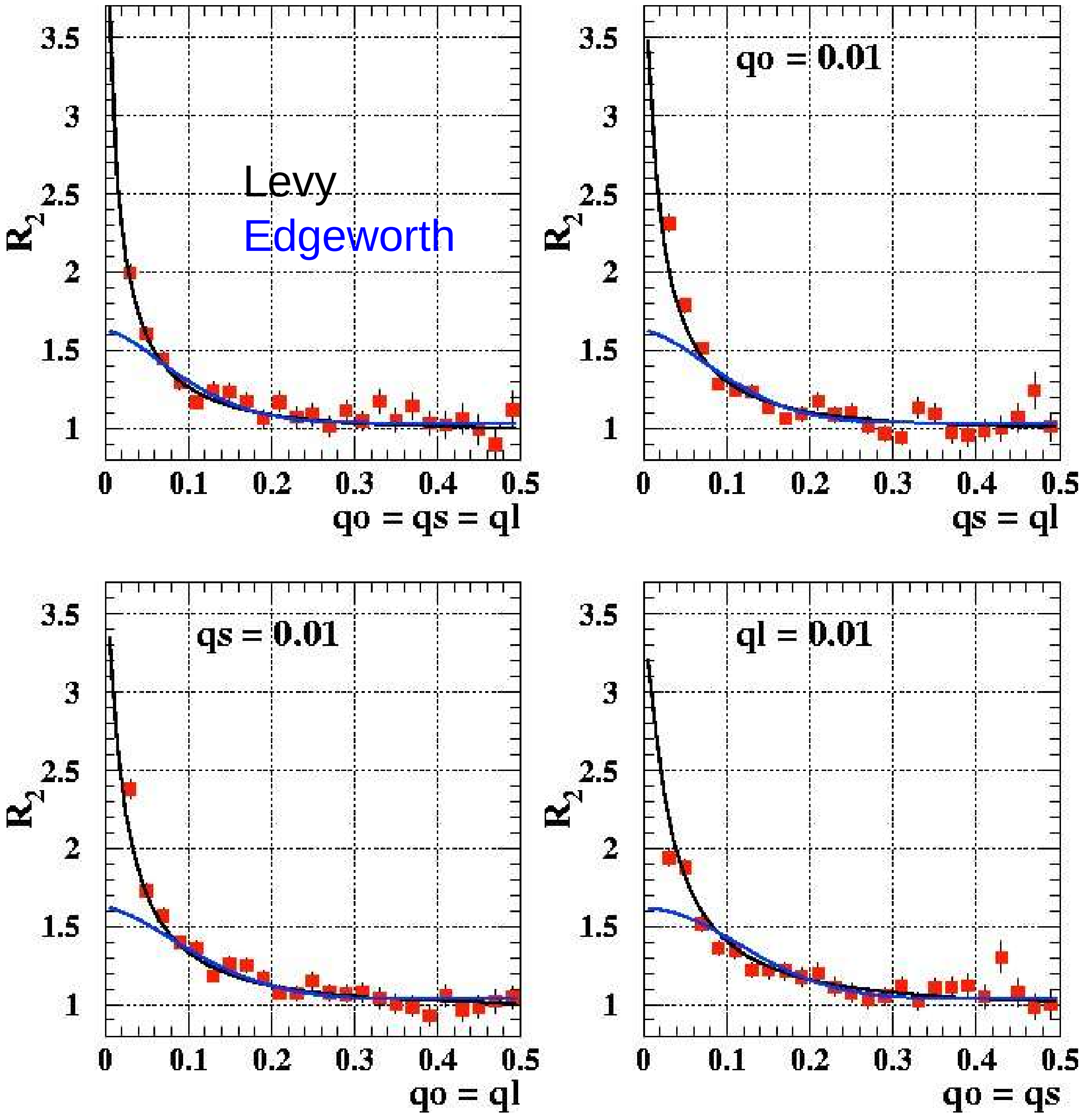
$\chi^2 / NDF = 1.32$



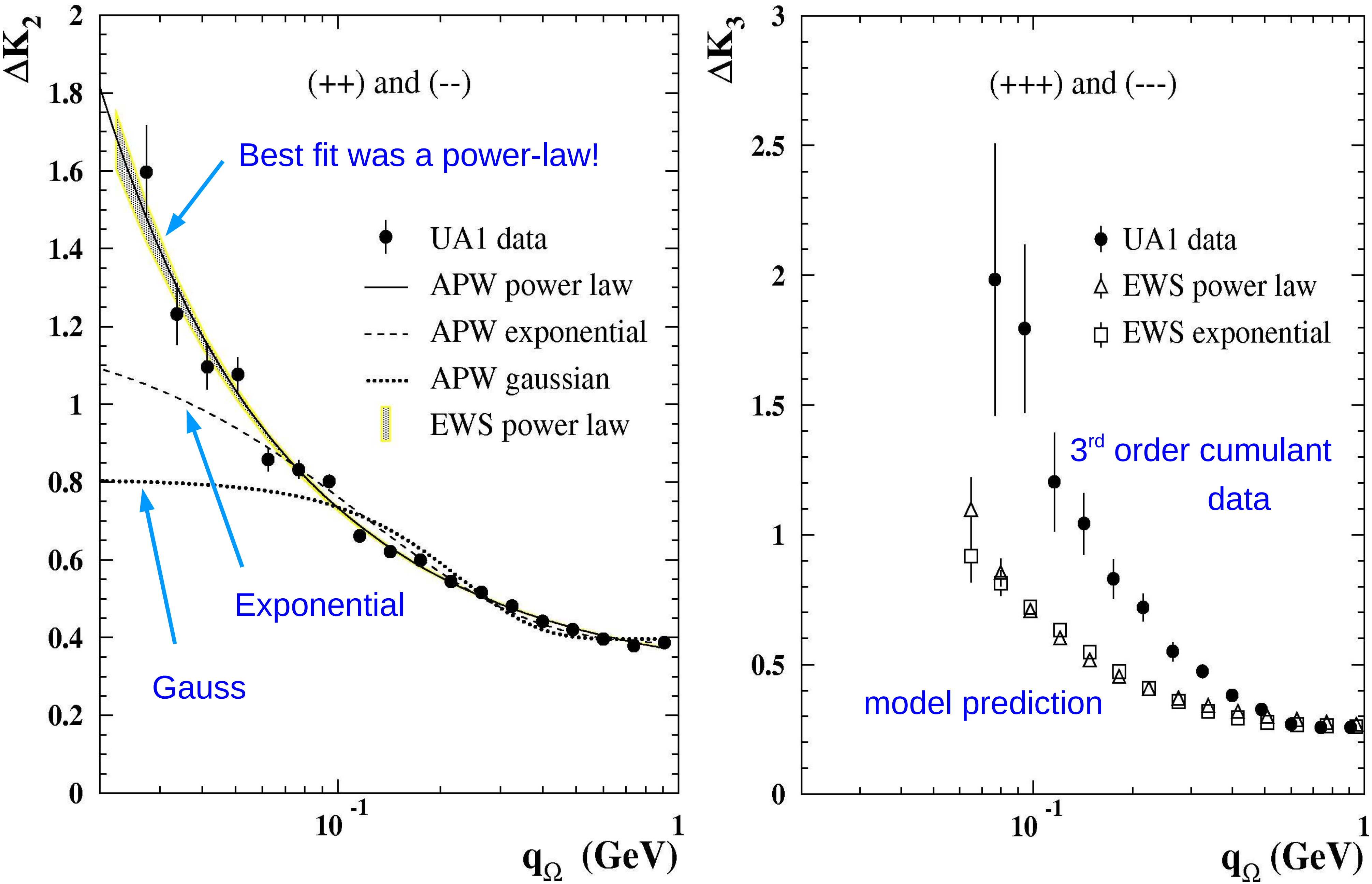


Edgeworth and Levy: representative plots on the diagonals





UA1 higher-order HBT (hep-ph/9702235)



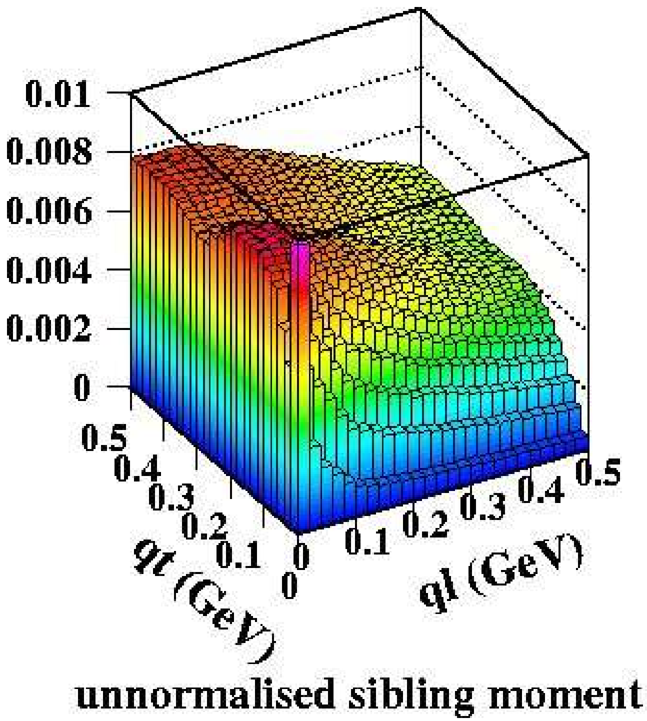
Summary

- Normalisation and correction issues very important
- qlong-qtransverse:
  - Simple Fits Fail (including power-law, cross-term gauss)
  - Levy OK but unstable
  - Two-component model yields “spherical halo” of approx 2.5fm and “prolate core” of 0.5-0.8fm
- 3D Bertsch-Pratt:
  - more of the same
  - even two-scale model fails (so far)
- Hadronic physics may differ from current AA-based approaches
- Higher-order correlations
- OUTLOOK: Lots of things to do (Kt, y, Coulomb, shape, jets ...)

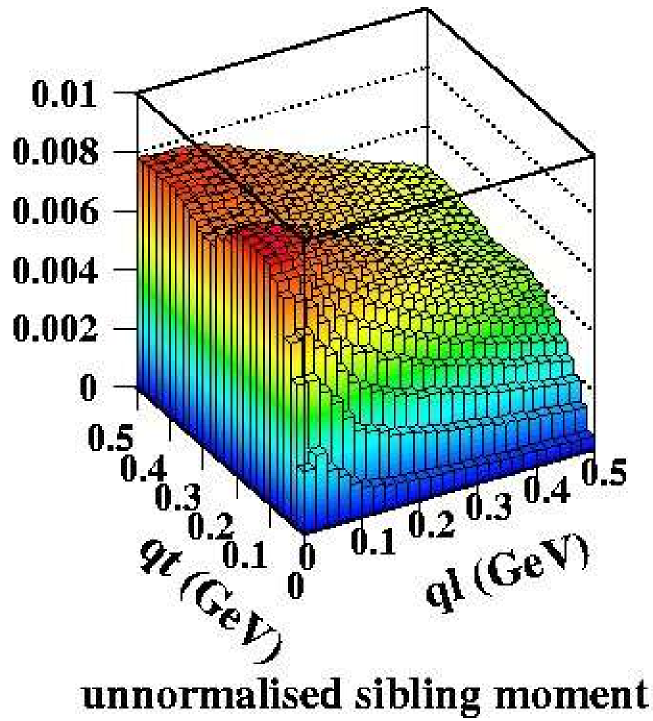
  BUT we must first understand the low-q peak
- Preservation of data (please!)

Unnormalised moments for ql-qt

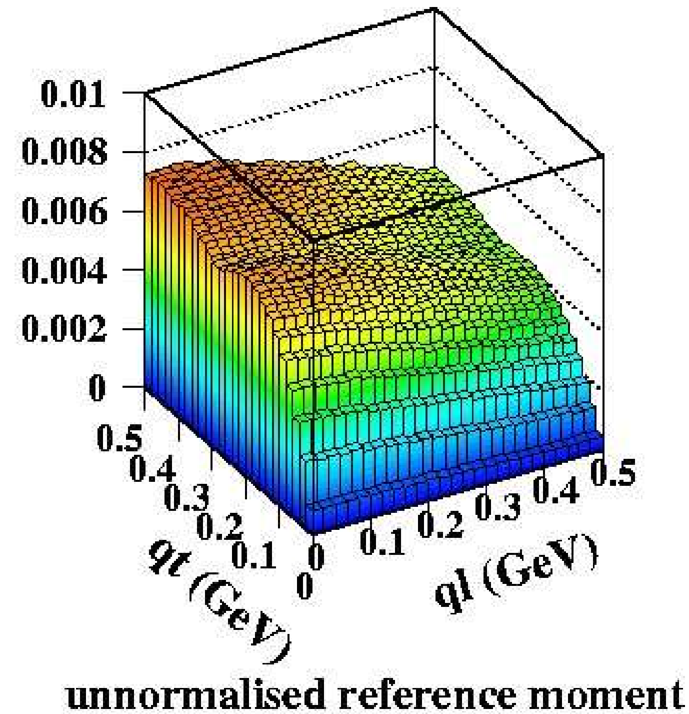
with Coulomb

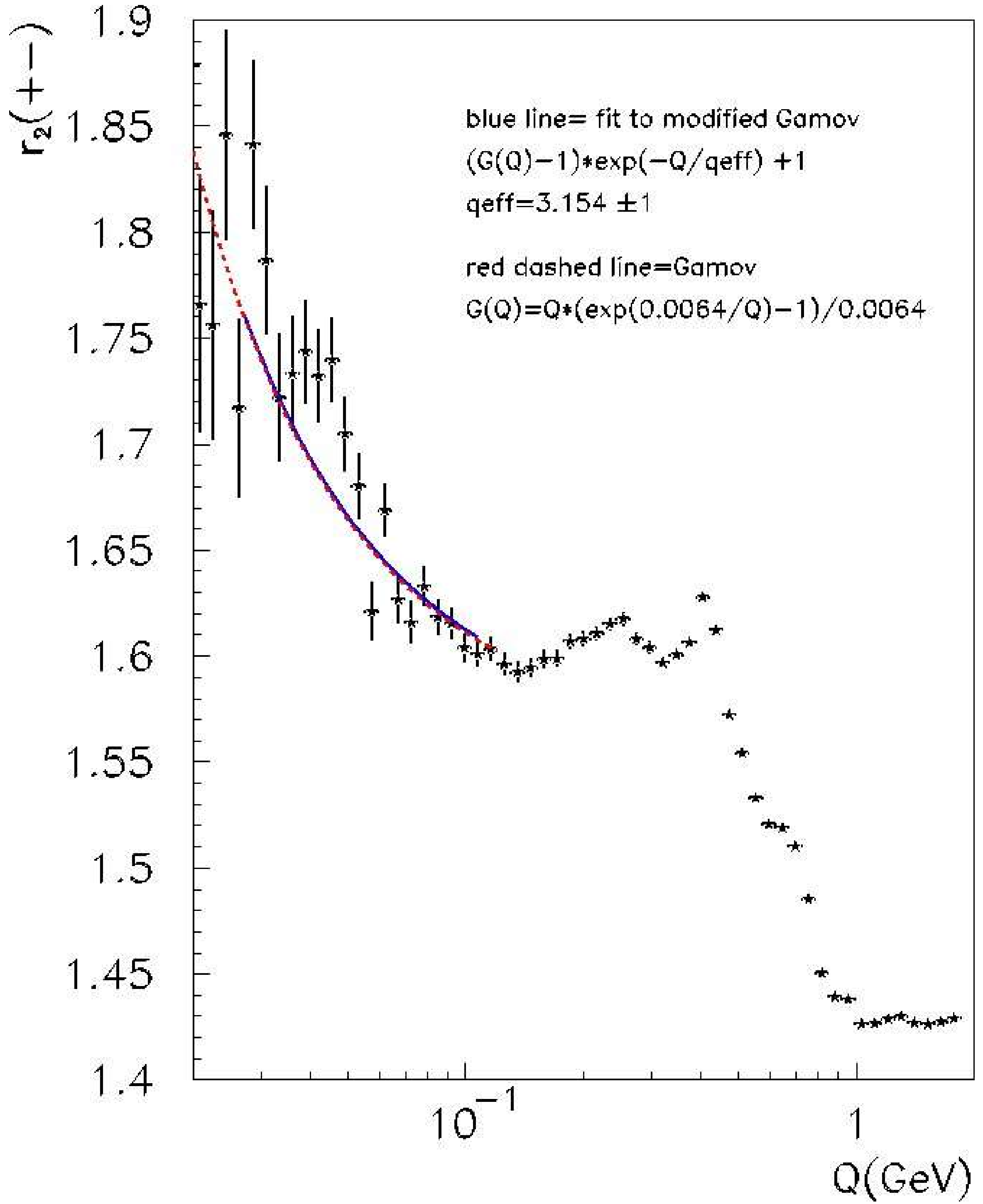


without Coulomb



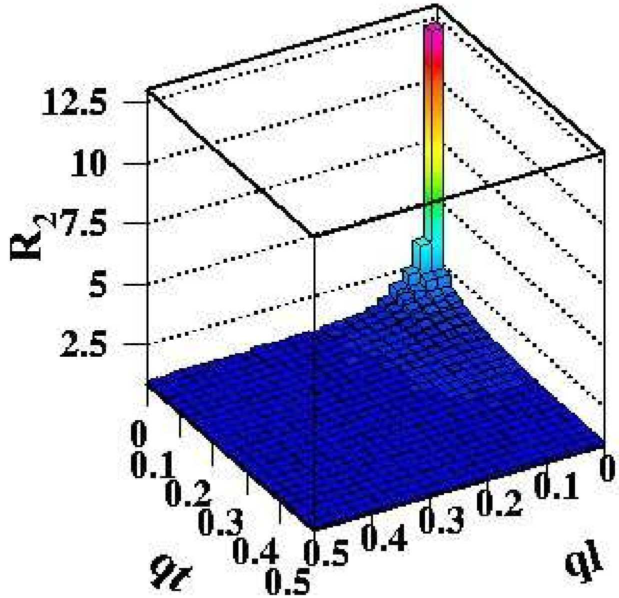
reference moment

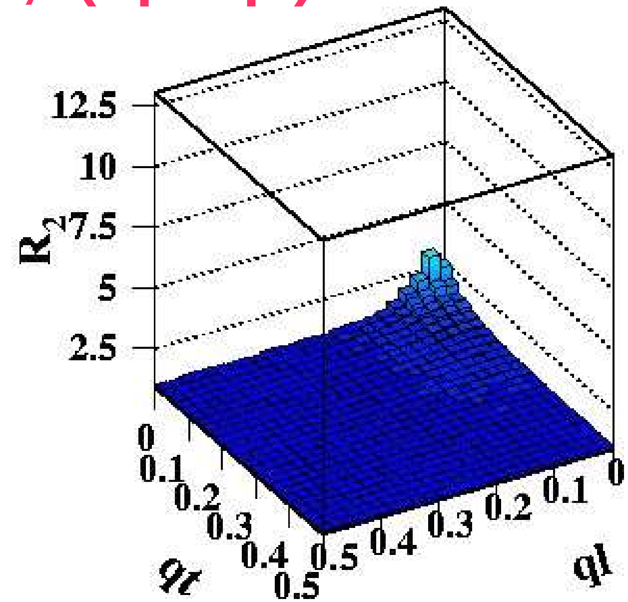



blue line= fit to modified Gamov
(G(Q)−1)*exp(−Q/qeff) +1
qeff=3.154 ±1
red dashed line=Gamov
G(Q)=Q*(exp(0.0064/Q)−1)/0.0064
r2(+−)
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
10−1
1
Q(GeV)

Effect of Coulomb correction, (ql-qt) data

Ignore bin with smallest (ql,qt) from now on.

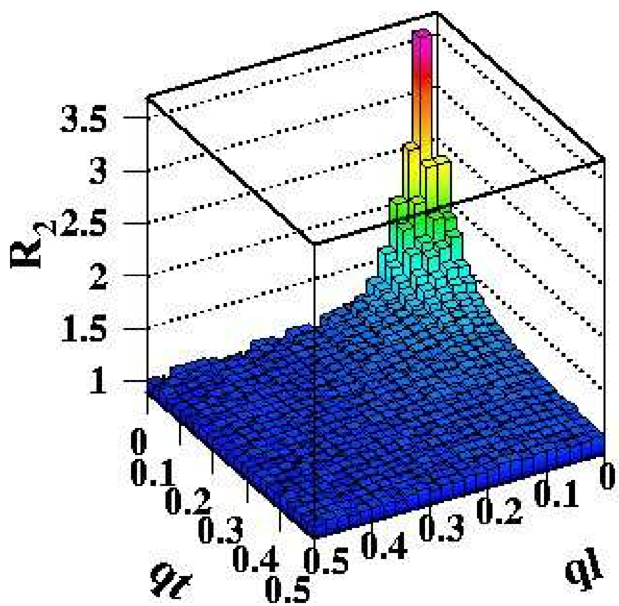


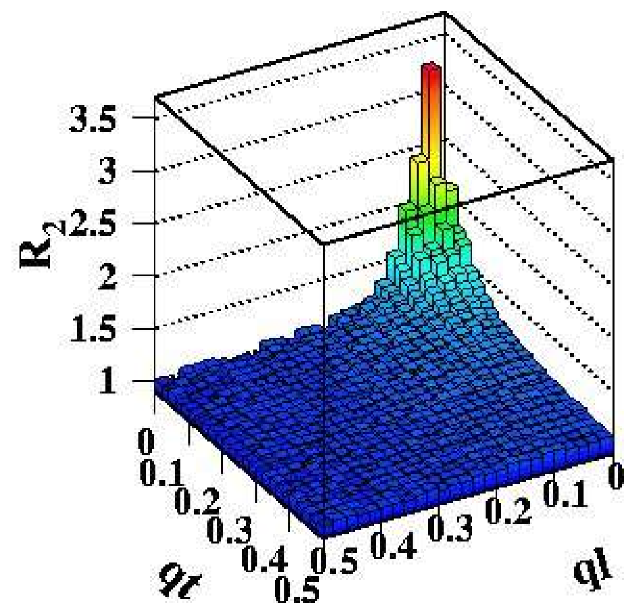


with Coulomb

no Coulomb

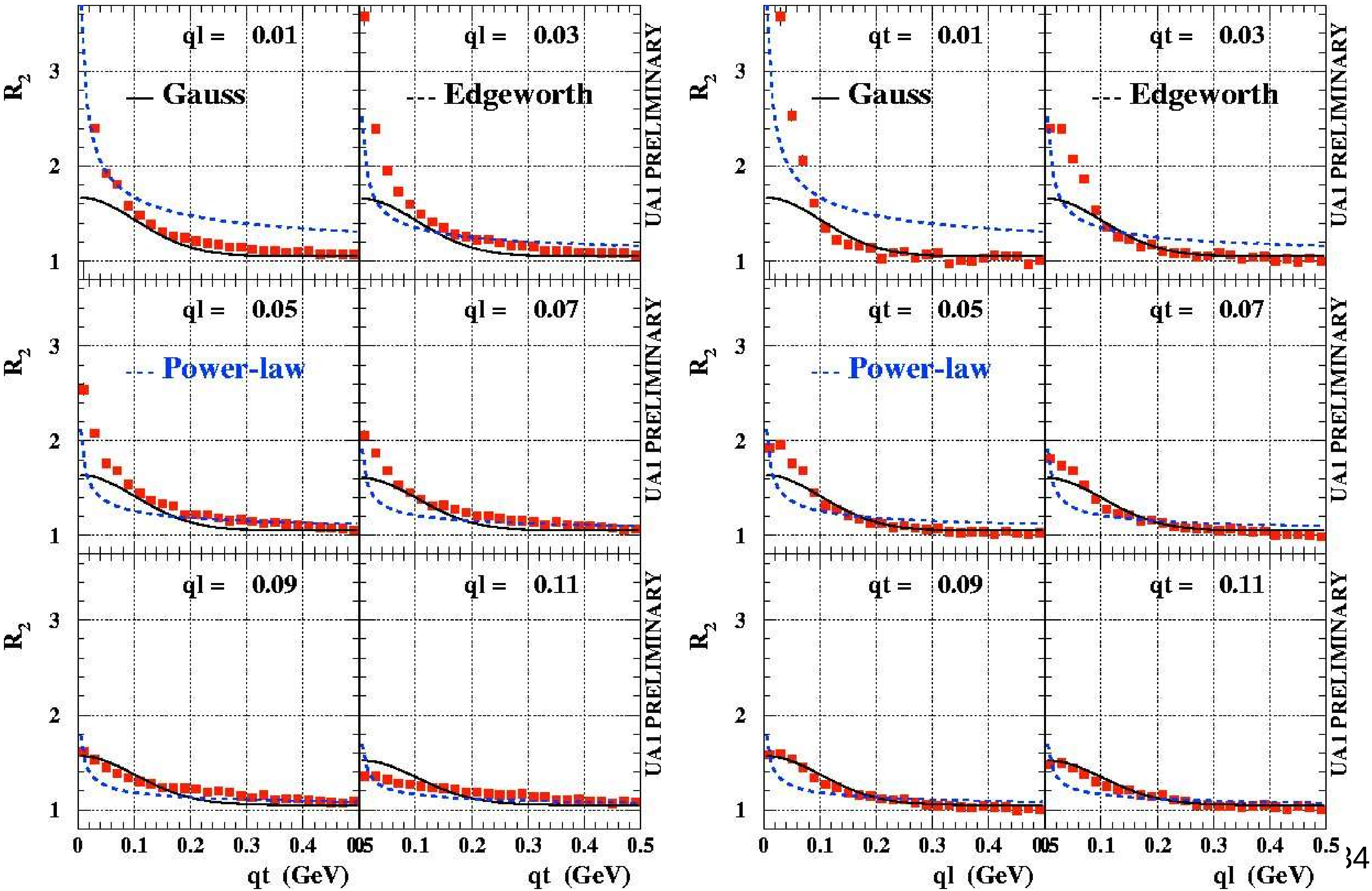
Nevertheless, note large intercept!





Edgeworth and power-law fits of R2(ql,qt)

fixed-ql slices fixed-qt slices



NO COULOMB: R2(ql,qt)

UA1 data

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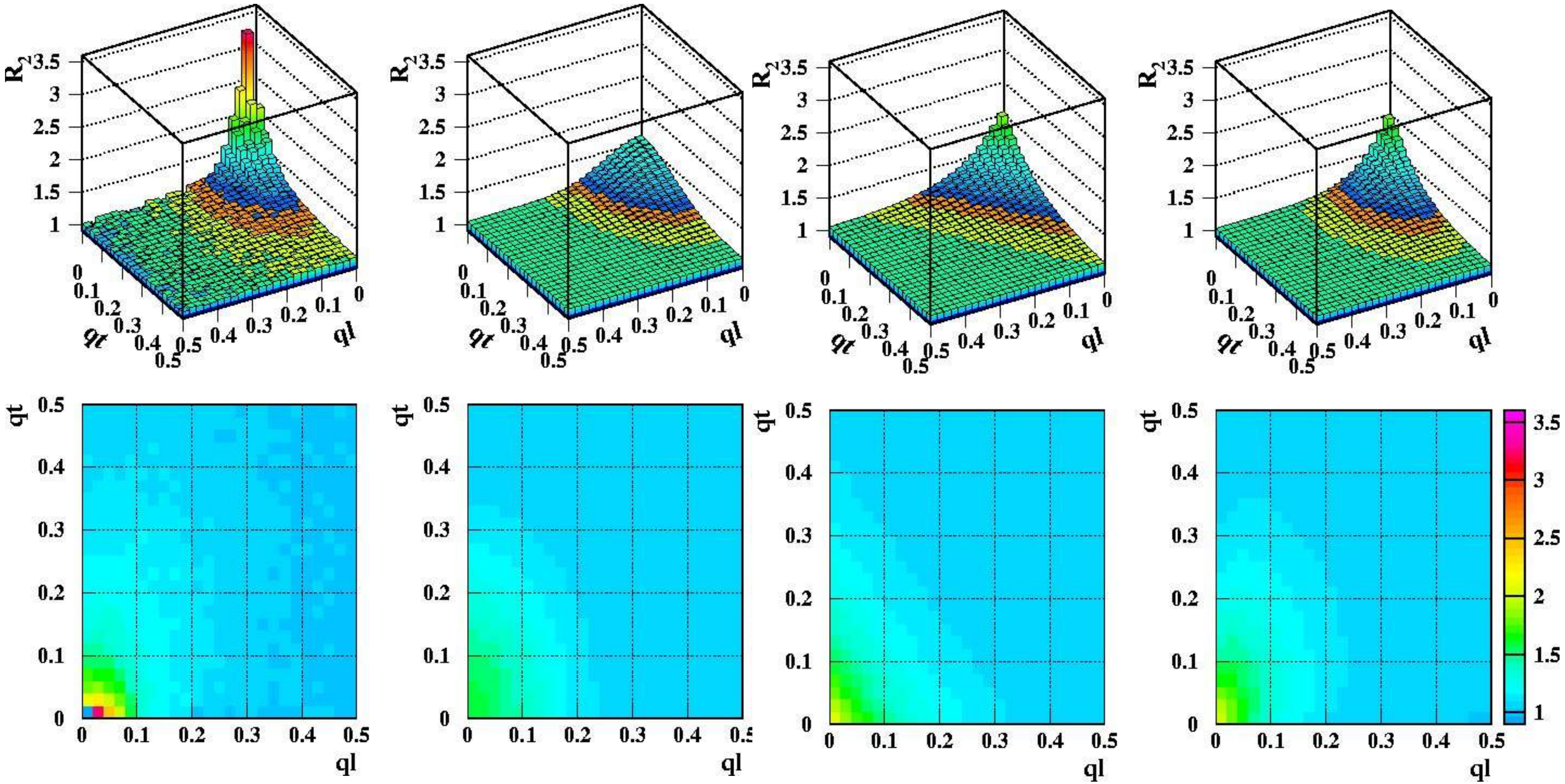
gauss with and without

$\chi^2 / NDF = 7.3$
exponential

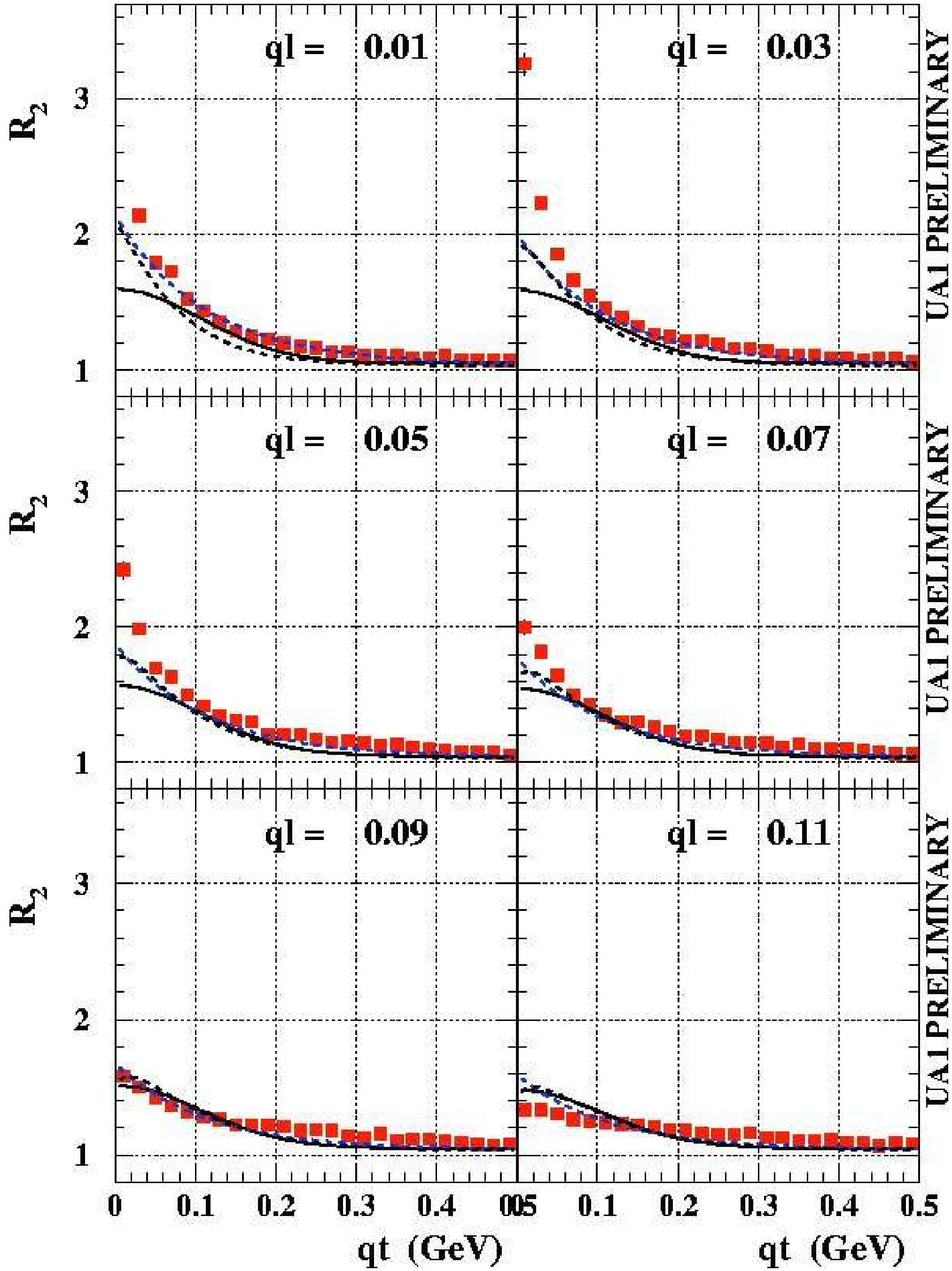
$\chi^2 / NDF = 4.7$
exponential with cross term



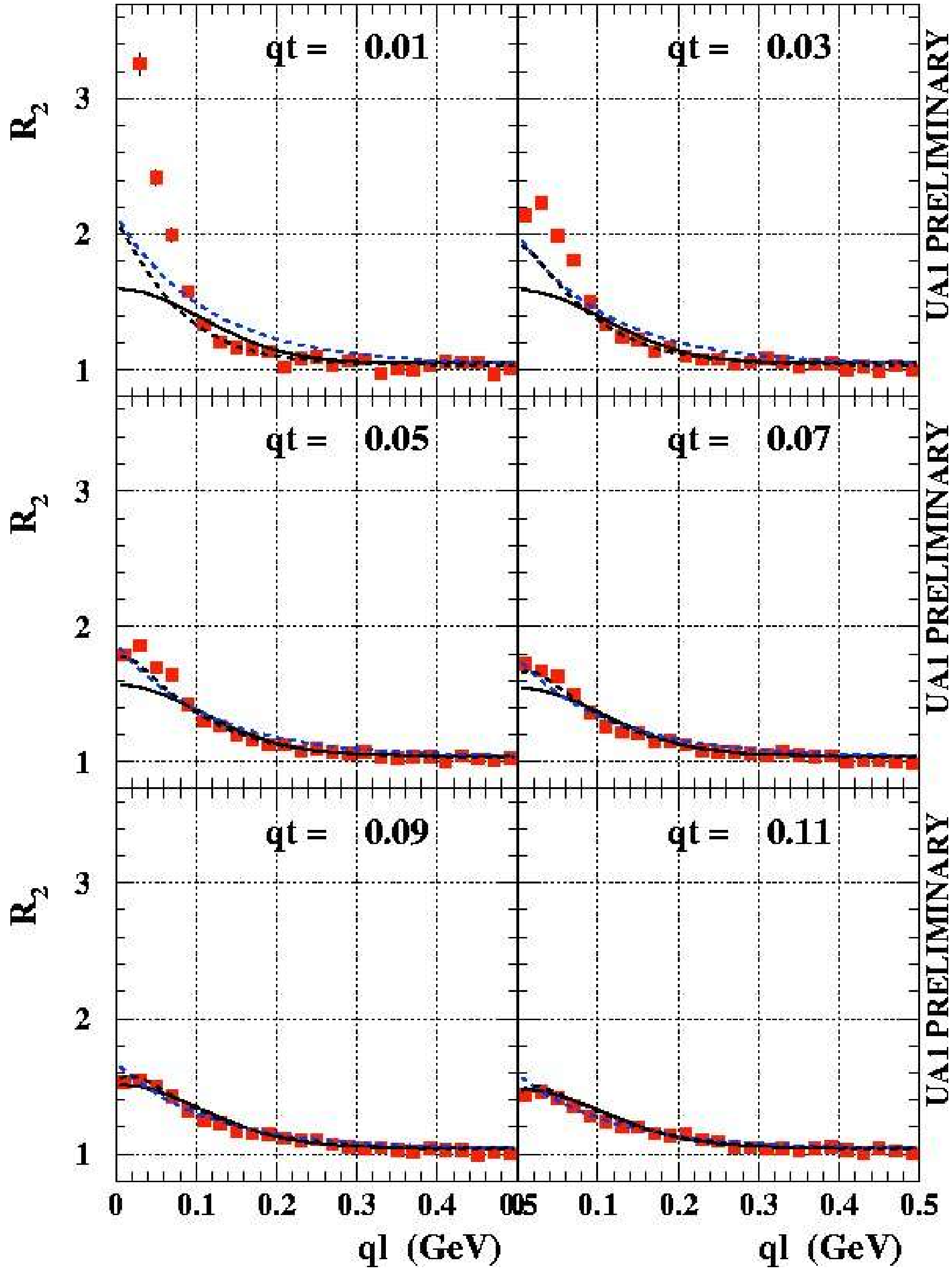
Eggers WPCF05

NO COULOMB R2(ql,qt)

fixed-ql slices



fixed-qt slices



Eggers WPCF05

Levy: fits with fixed

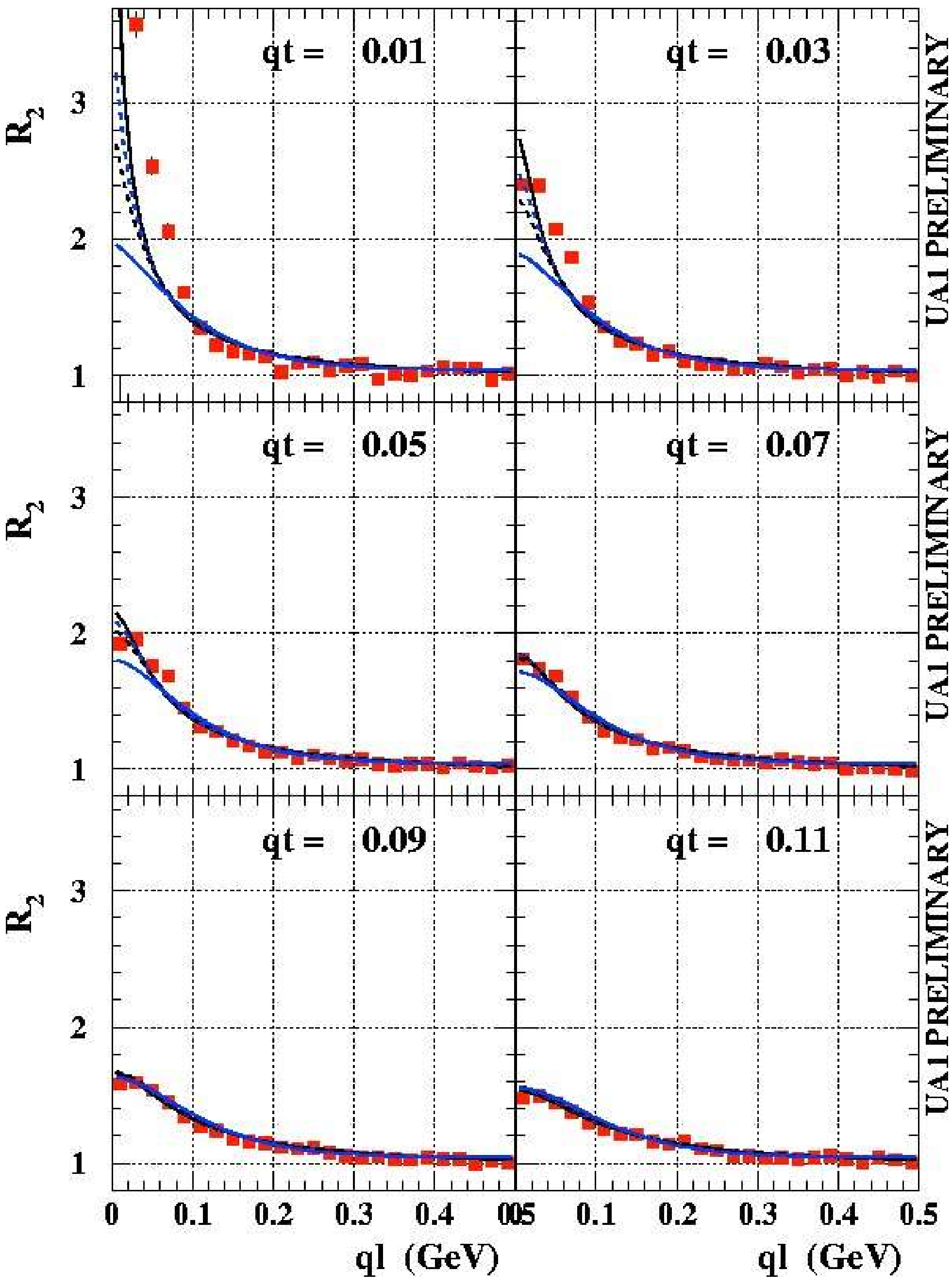
Curves for fixed

α = 0.22

α = 0.50

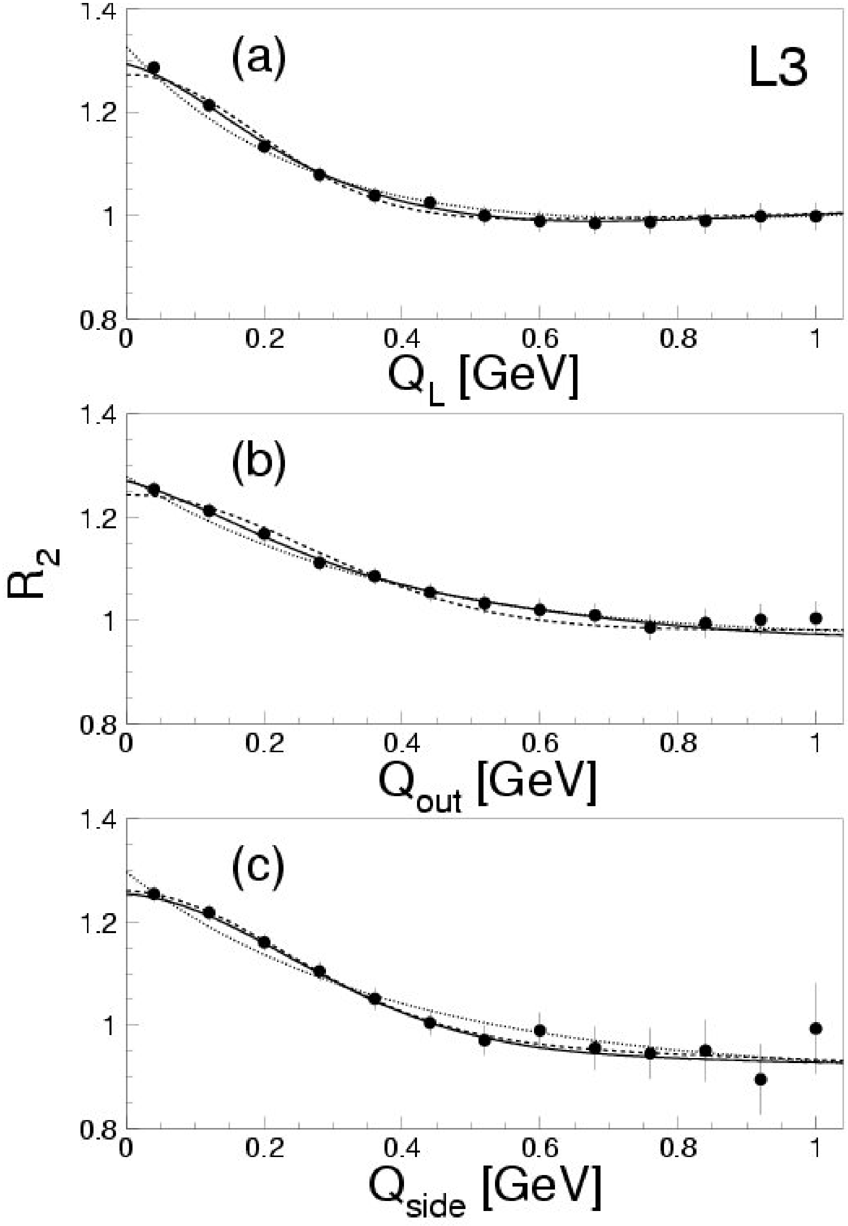
α = 0.70

α = 1.30



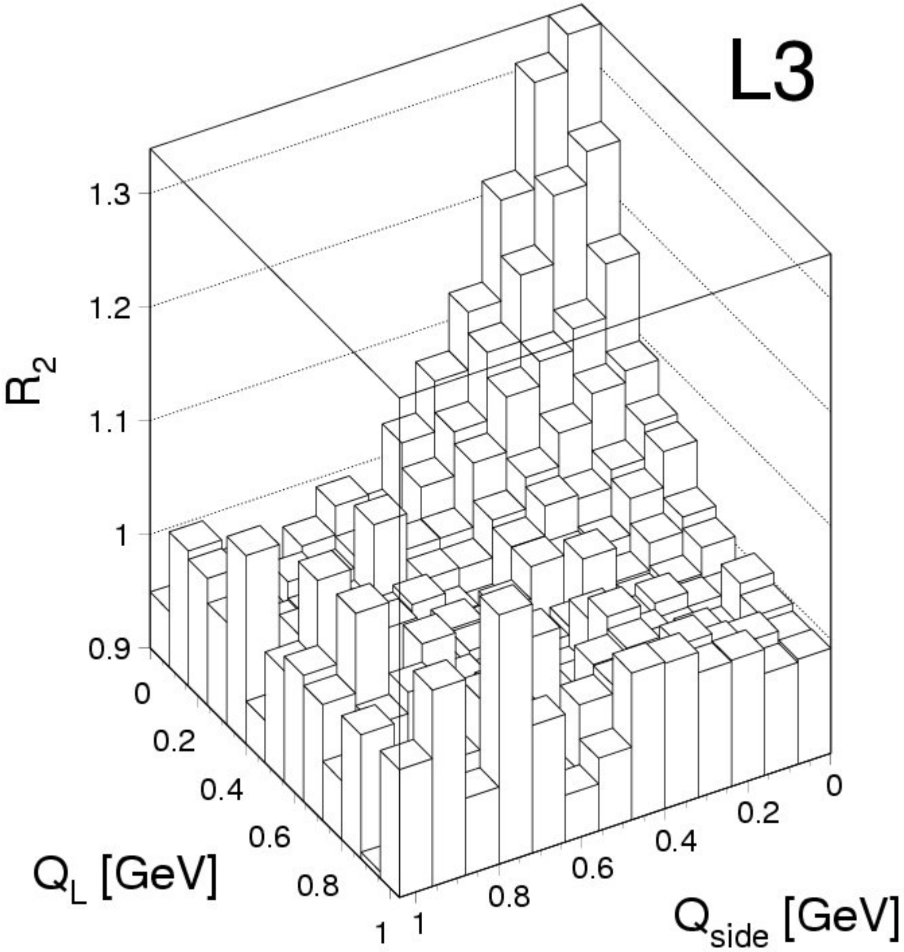
R_2(qo,qs,ql) by L3

PLB 458, 517 (1999)

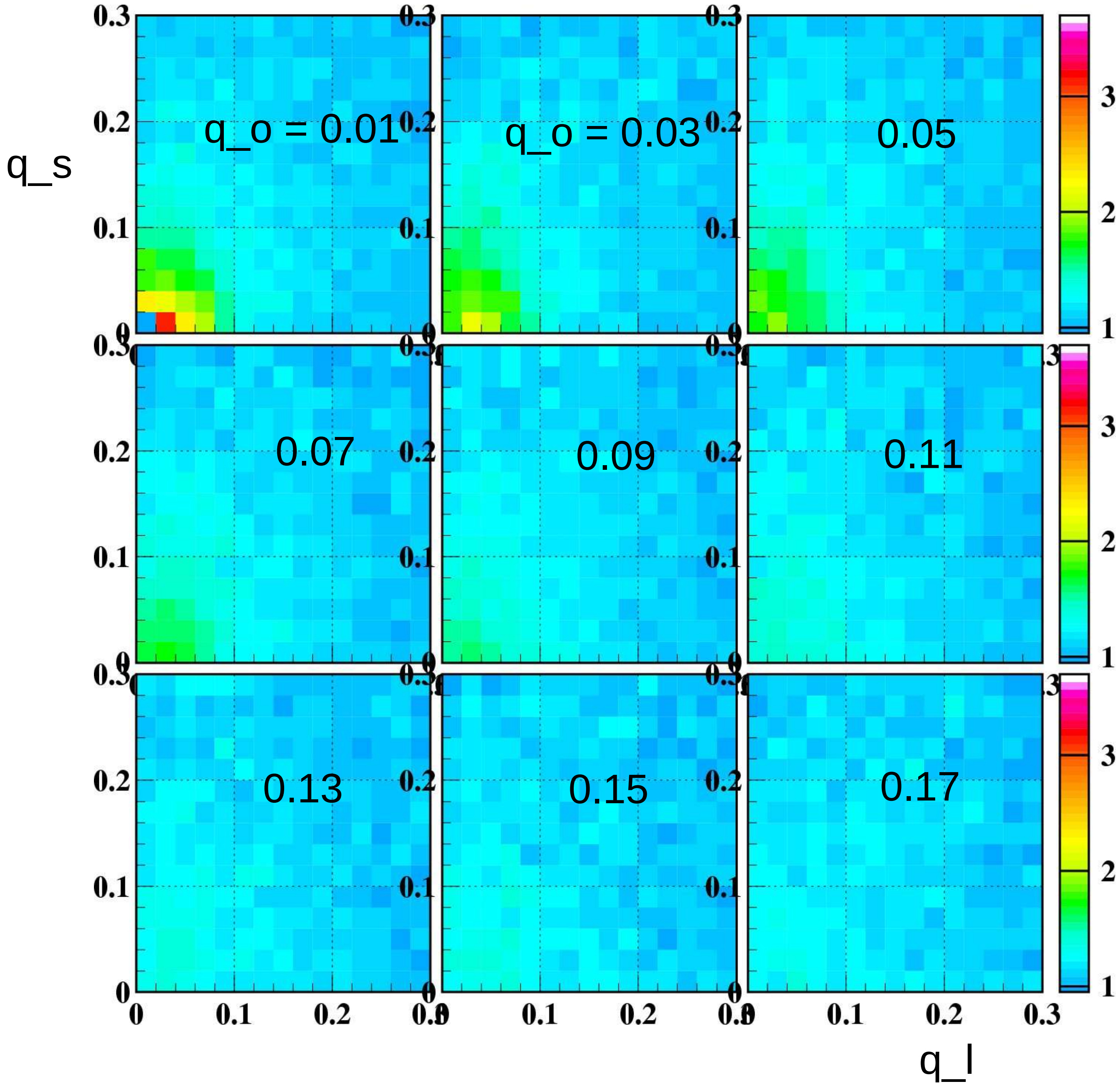


Projections of 240MeV slices onto the axes (left)

(ql,qs) surface (below)



UA1 3-dimensional data for q_l q_s q_o, no Coulomb



Eggers WPCF05