Charm enhancement at the LHC due to nonlinear gluon evolution

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Based on

K.J. Eskola, V.J.Kolhinen and R.Vogt, hep-ph/0310111

A.D., R.Vogt, M.Bondila, K.J.Eskola and V.J. Kolhinen, hep-ph/0403098

Outline

- The (x,Q^2) range probed with charm at LHC energy
- Effect of nonlinear evolution terms on c-quark production
- Possibility to address the effect in the ALICE experiment

Nonlinear terms in gluon evolution

(see talk by Vesa Kolhinen)

$$\frac{\partial xg(x,Q^2)}{\partial \log Q^2} = \left.\frac{\partial xg(x,Q^2)}{\partial \log Q^2}\right|_{DGLAP} - O\left(\left(xg(x,Q^2)\right)^2\right)$$

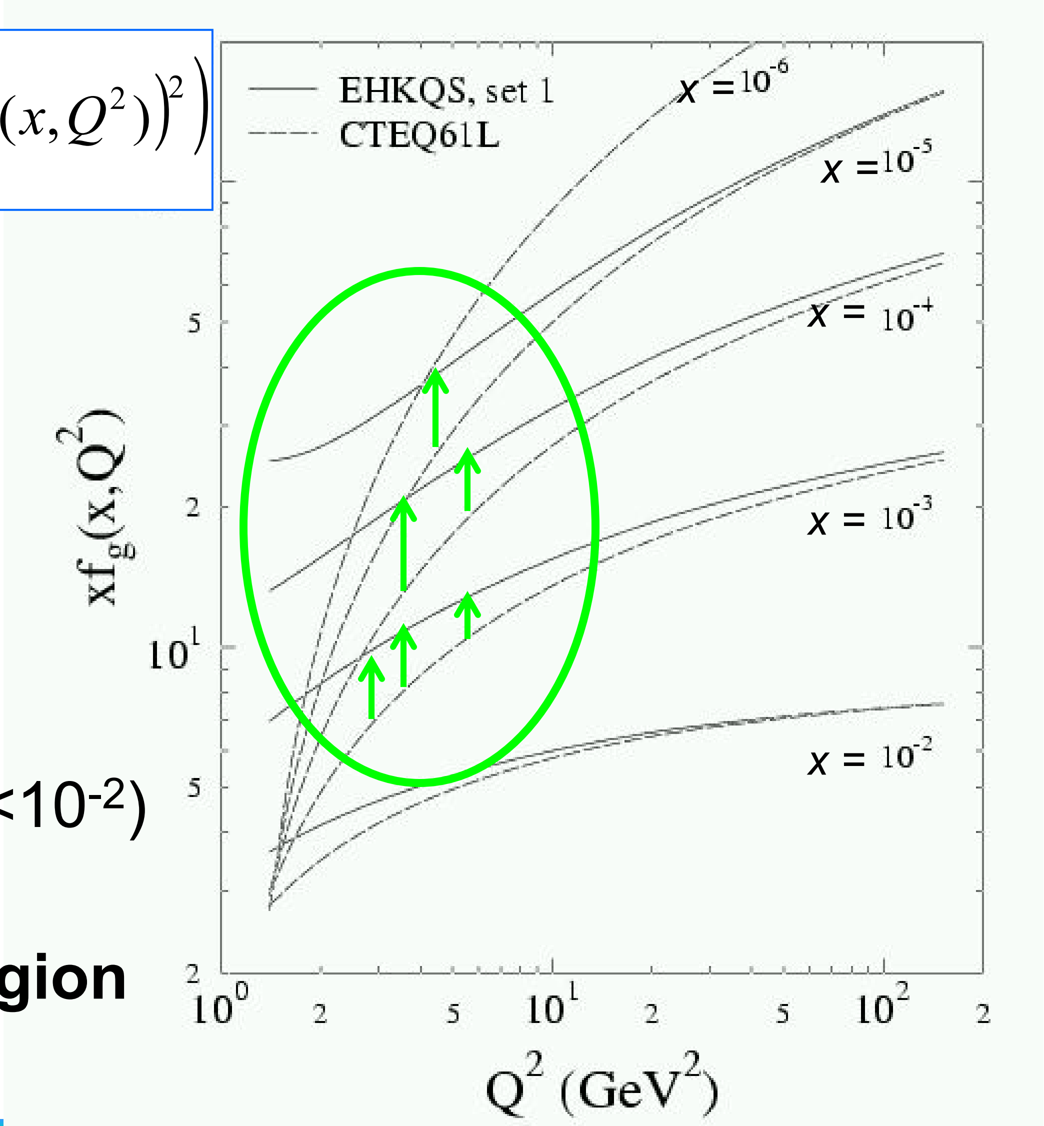
nonlinear (quadratic) correction has "–" sign

→ Q^2 evolution is ***slower***

⬇

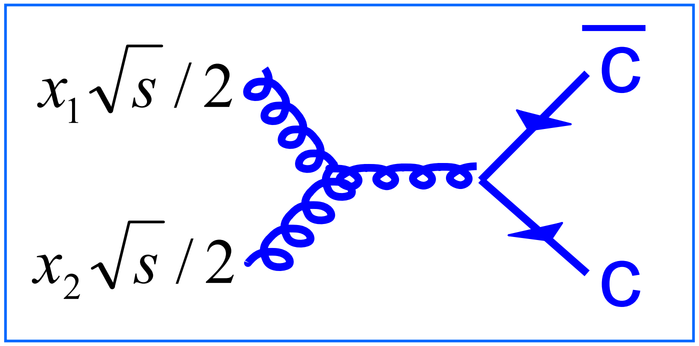
$xg(x,Q^2)$ at low Q^2 (<10 GeV^2) and x (<10^{-2}) is larger than in DGLAP

→ **need probe of this region**



Charm at √s = 14 TeV: x,Q² range (1)

- Simple estimate: $gg \to c\bar{c}$



$$M_{c\bar{c}}^2 \approx \hat{s} = x_1 x_2 s \qquad y_{c\bar{c}} = \frac{1}{2}\ln\left(\frac{x_1}{x_2}\right)$$

$$x_1 = \frac{M_{c\bar{c}}}{\sqrt{s}}\exp(+y_{c\bar{c}}) \qquad x_2 = \frac{M_{c\bar{c}}}{\sqrt{s}}\exp(-y_{c\bar{c}})$$

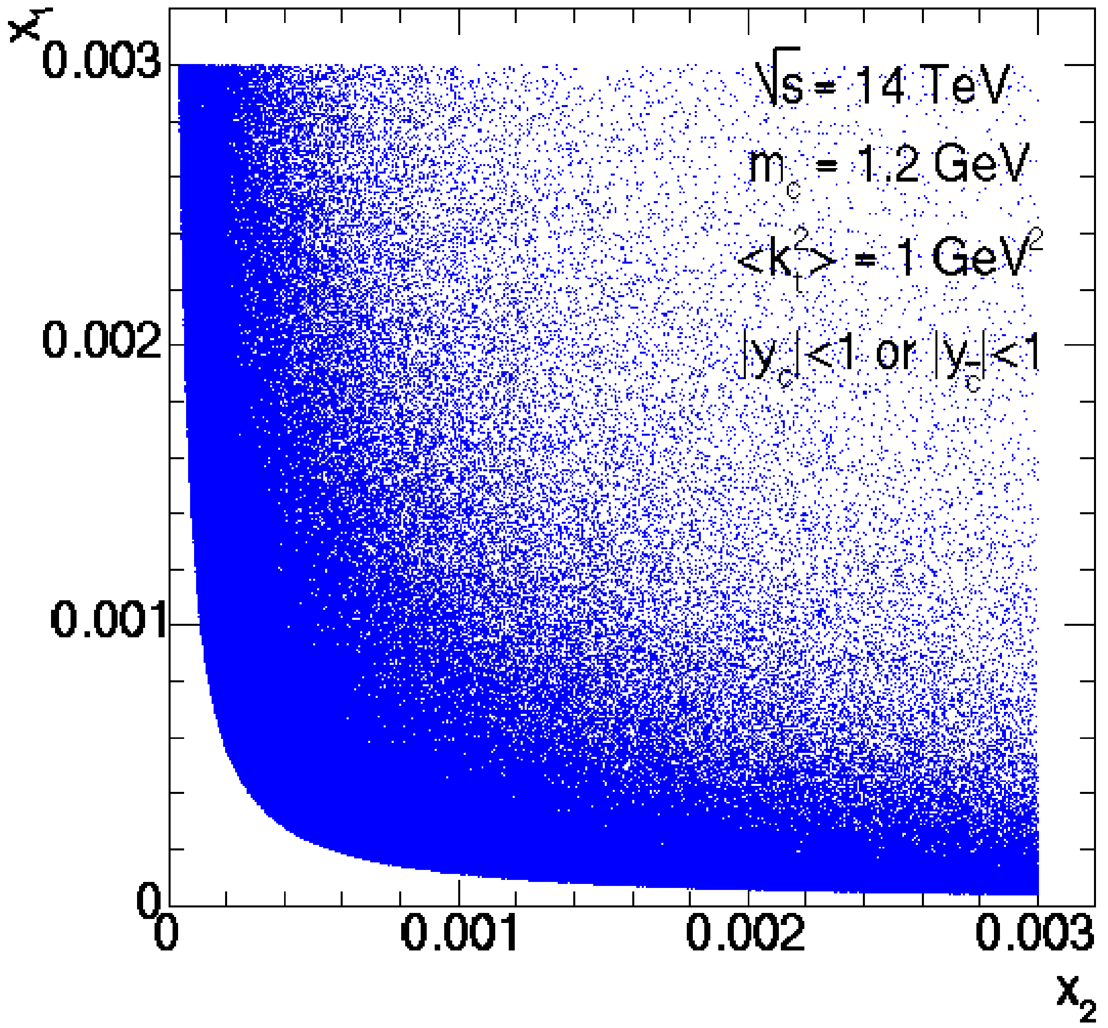
$$\sqrt{s} = 14\,\mathrm{TeV},\ m_c = 1.2\,\mathrm{GeV},\ y_{c\bar{c}} = 0,\ p_t \to 0$$

$$Q^2 \approx M_{c\bar{c}}^2 \geq (2m_c)^2 = 5.8\,\mathrm{GeV}^2$$

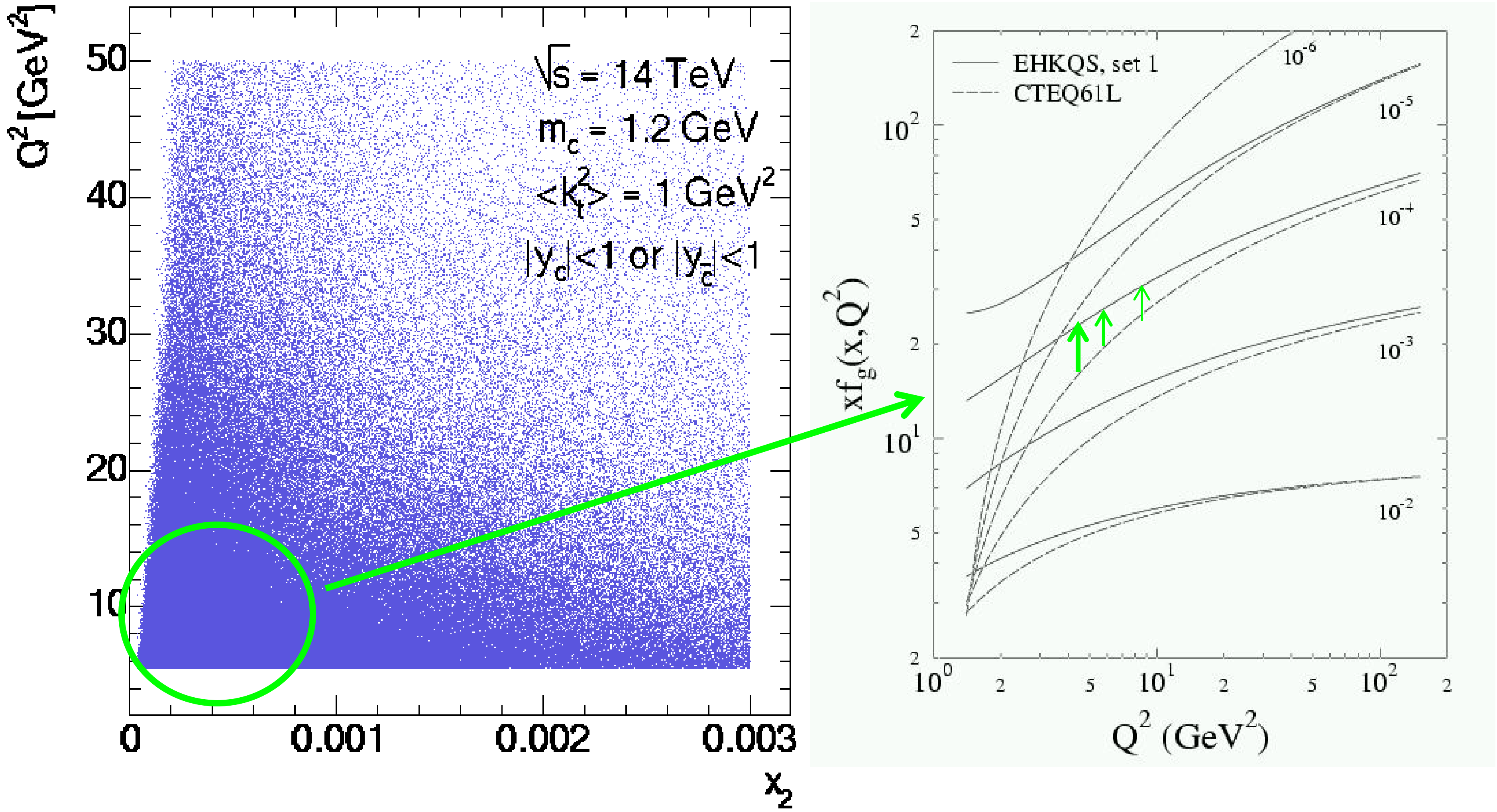
$$x_1 \sim x_2 \geq 2\times10^{-4}$$

Charm at $\sqrt{s}$ = 14 TeV: x,Q^2 range (2)

- PYTHIA simulation (LO): $gg \to c\bar{c}$



Charm at $\sqrt{s}$ = 14 TeV: x,Q^2 range (3)



Charm production: pQCD parameters choice

- Two sets of parameters that best describe available data:

m_c = 1.3 GeV

$\mu_R = \mu_F = Q = m_c$

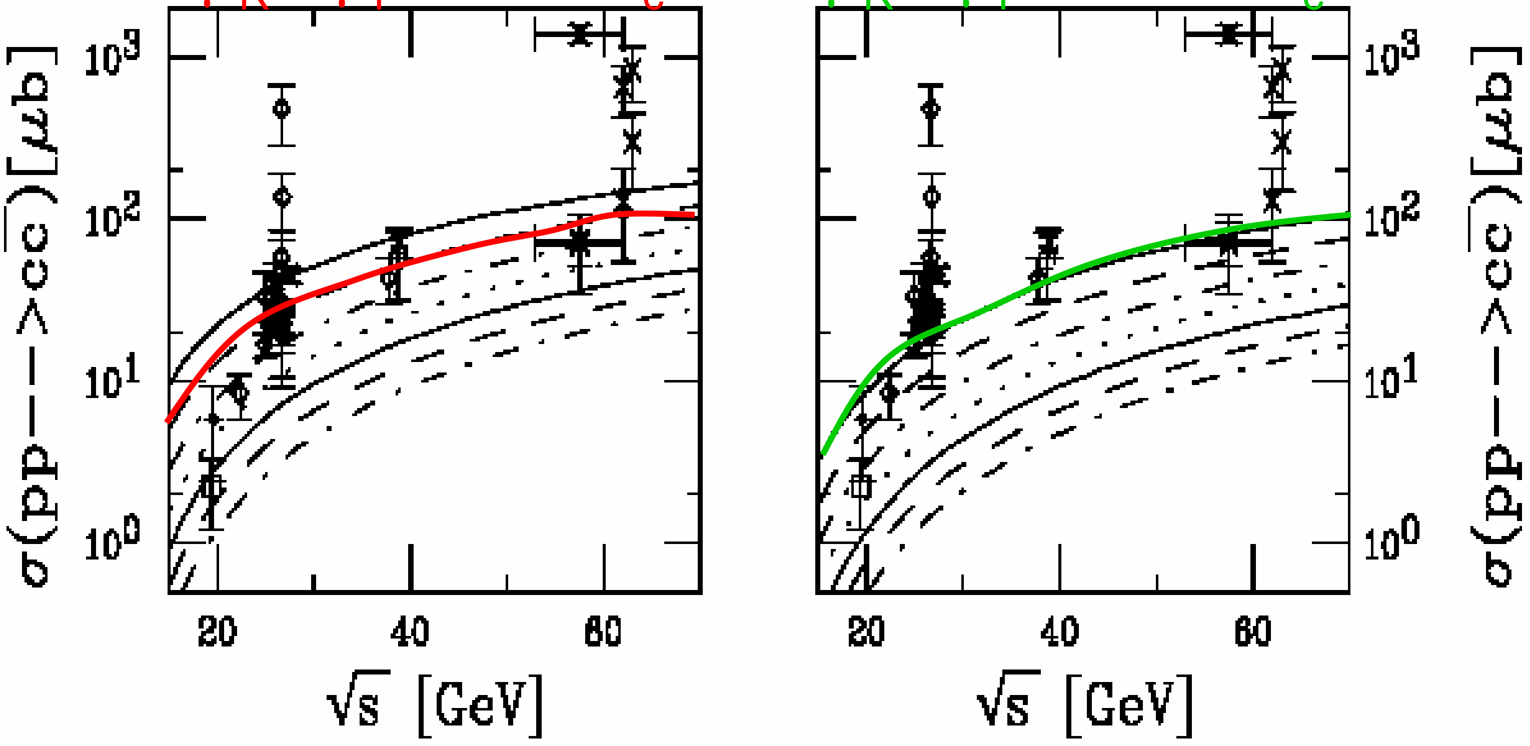
m_c = 1.2 GeV

$\mu_R = \mu_F = Q = 2m_c$

m_c =
1.2 GeV

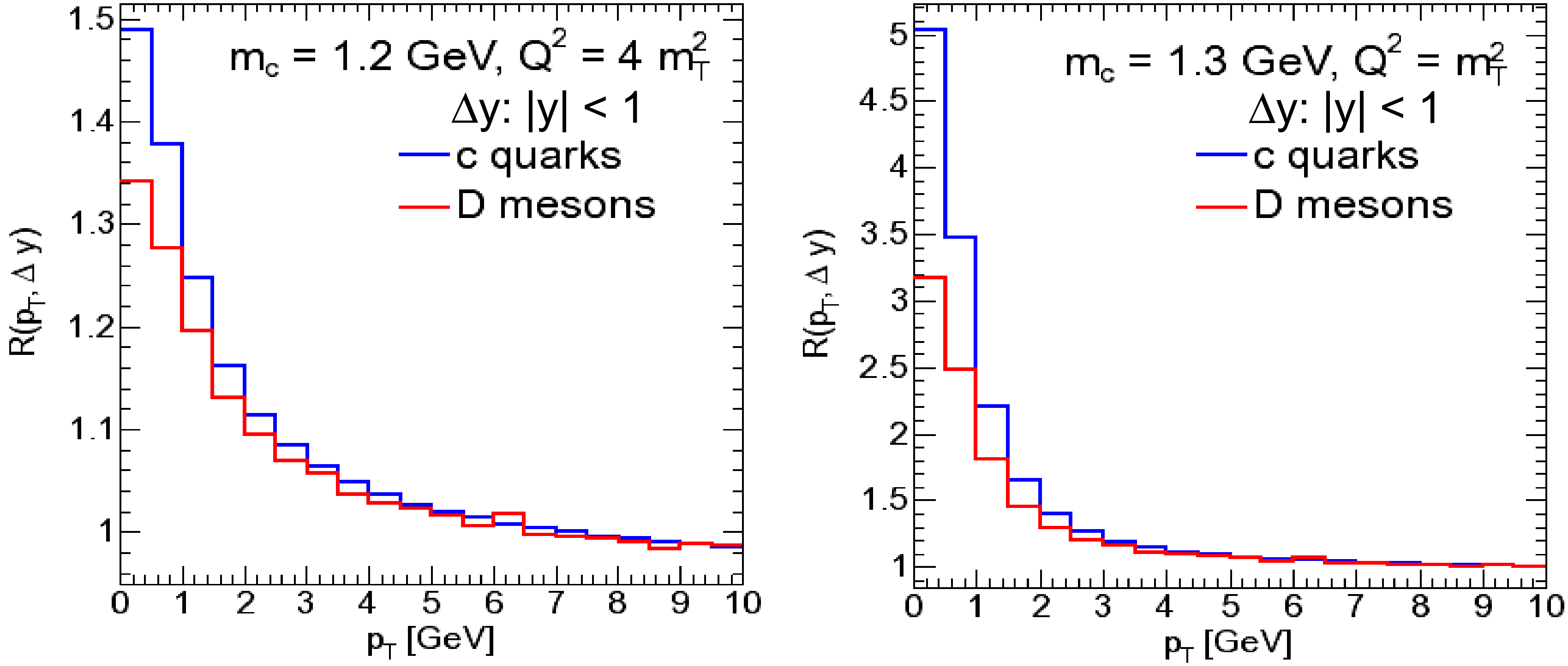
↓

1.8 GeV



NLO pQCD calc. by R. Vogt

Charm: nonlinear/DGLAP vs p_t



- Strongly dependent on choice of mass and scale* (Q^2)
- Varies from ×1.5 to ×5
- **“Enhancement” limited to p_t < 2 GeV/*c***

  ➡ **need to measure D production down to very low p_t**
- Caveat: effect currently calculated only at LO

* $\mu_R = \mu_F = Q$

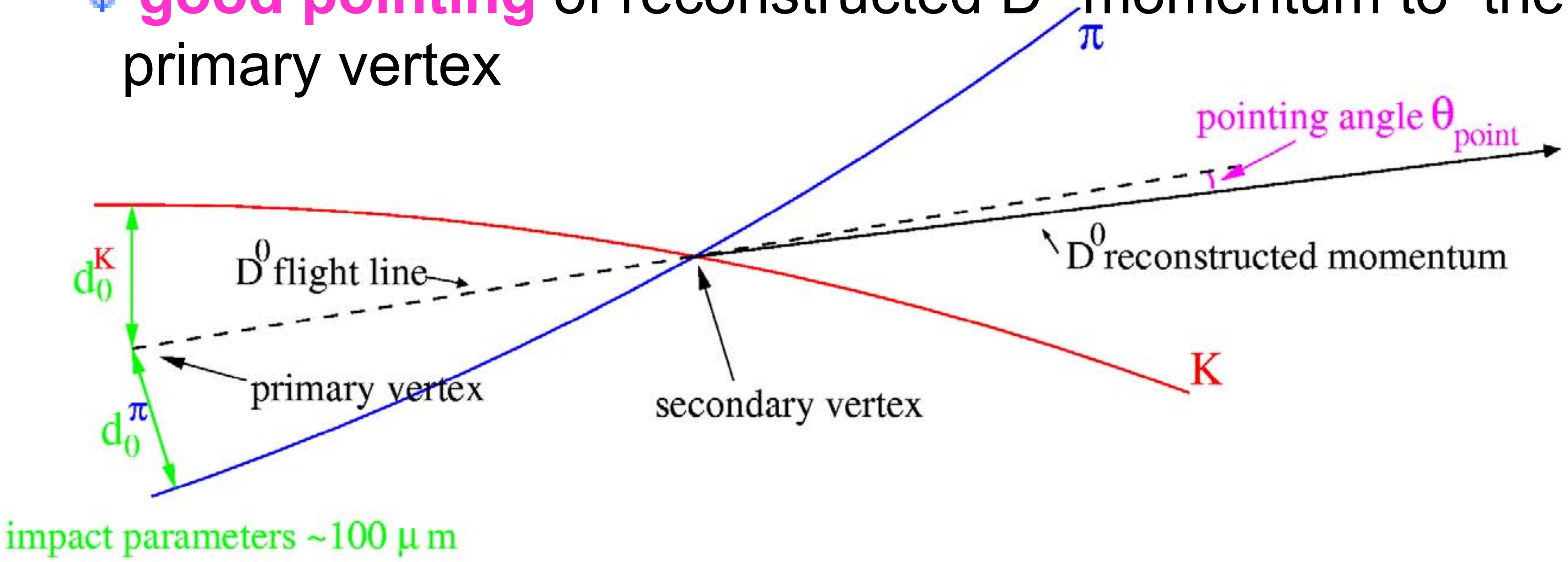
Charm detection in ALICE

- Excellent tracking in $|\eta| < 0.9$ with impact parameter resolution better than 60 μm for $p_t > 1$ GeV/c
- Low field (0.4 T) + K ID via time-of-flight

  ➡ exclusive $D^0 \rightarrow K^-\pi^+$ down to very low p_t (~ 0)

Selection of D^0 candidates

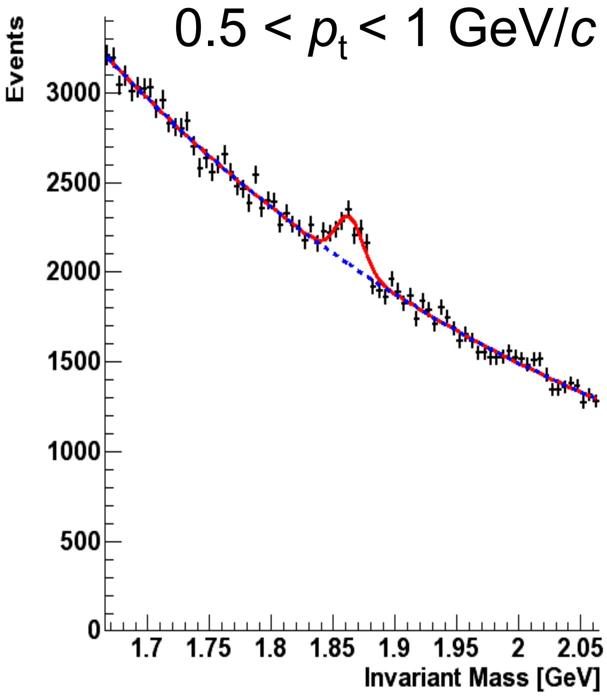
- Large combinatorial background
- Main selection: displaced-vertex selection
  - pair of tracks with **large impact parameters**
  - **good pointing** of reconstructed D^0 momentum to the primary vertex

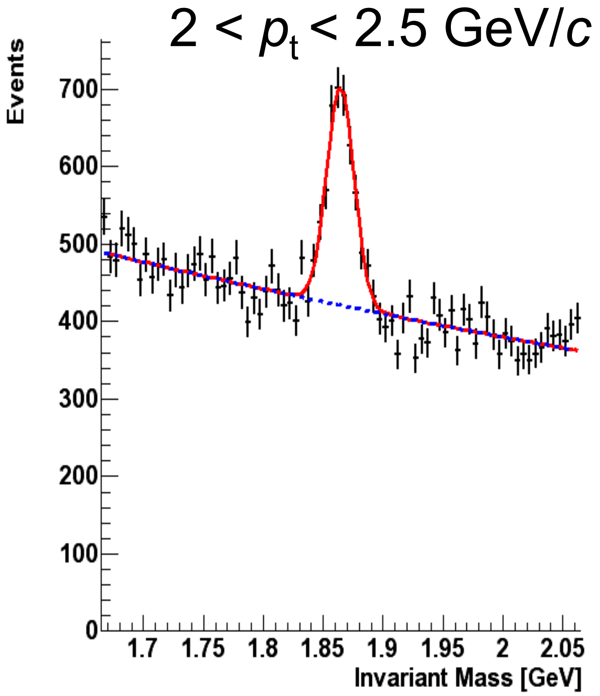


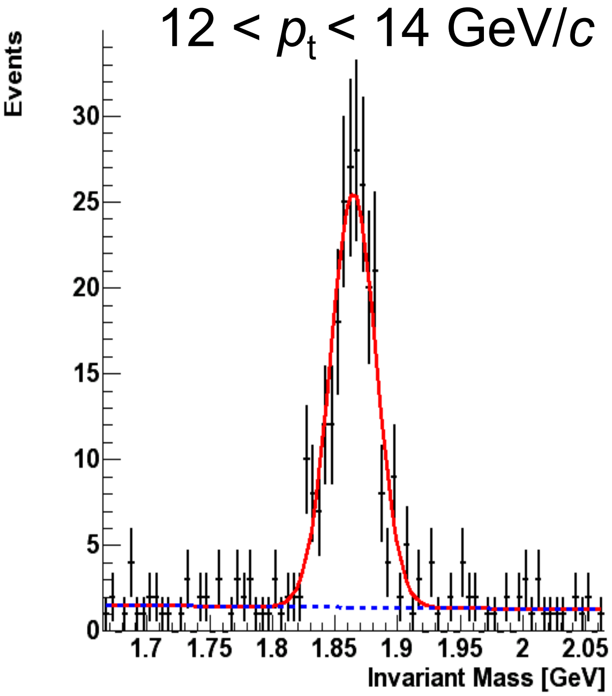
Invariant mass analysis to “count” real D^0

Results for pp collisions

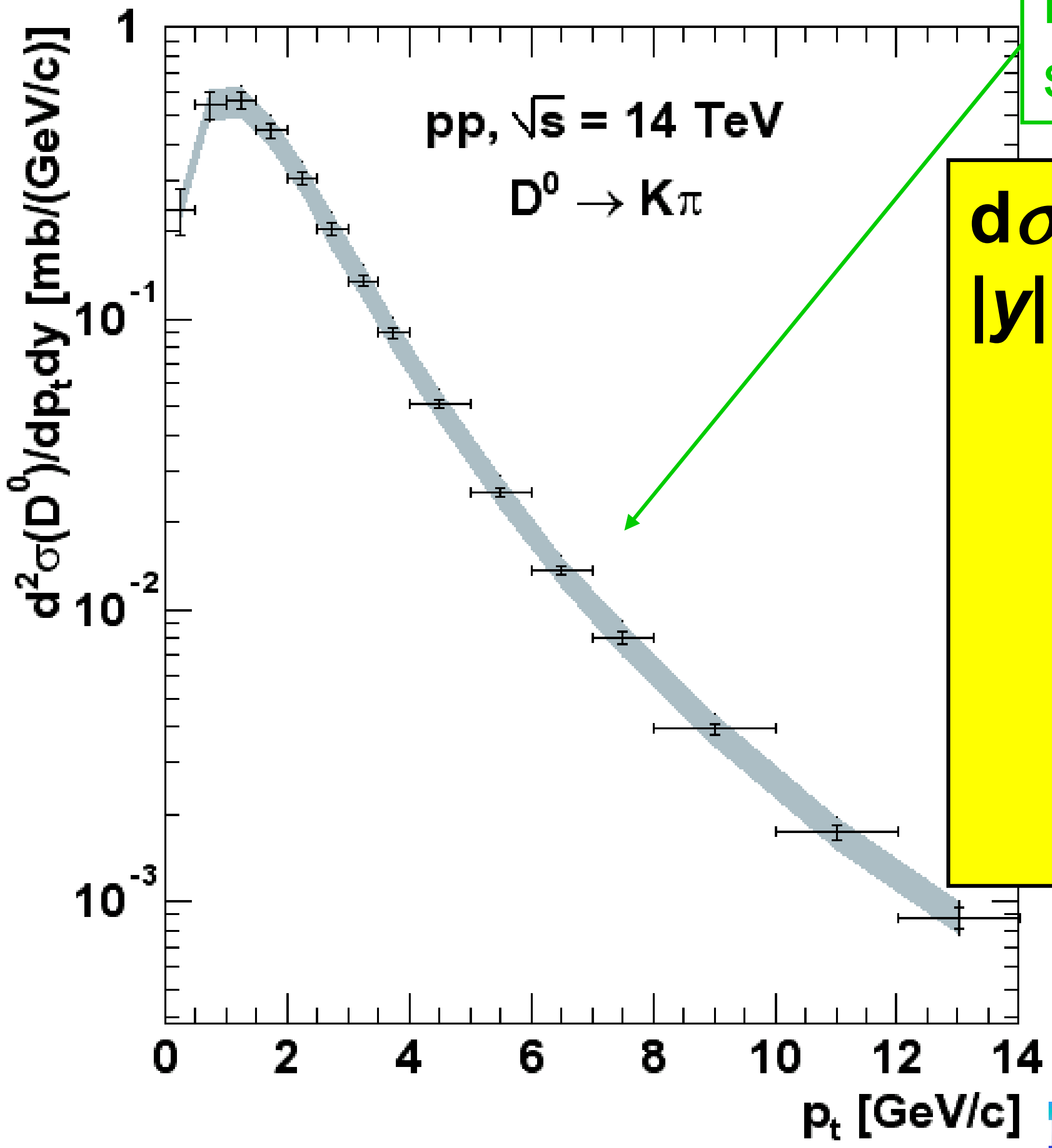
S/B initial (M±3σ)	S/evt final (M±1σ)	S/B final (M±1σ)	Significance $S/\sqrt{S+B}$ (M±1σ)
$2 \cdot 10^{-3}$	$1.9 \cdot 10^{-5}$	11 %	44 (for 10^9 evts, ~9 months at 10^{30} cm^{-2}s^{-1})


$0.5 < p_t < 1$ GeV/c


$2 < p_t < 2.5$ GeV/c


$12 < p_t < 14$ GeV/c

Meaurement of D^0 cross section



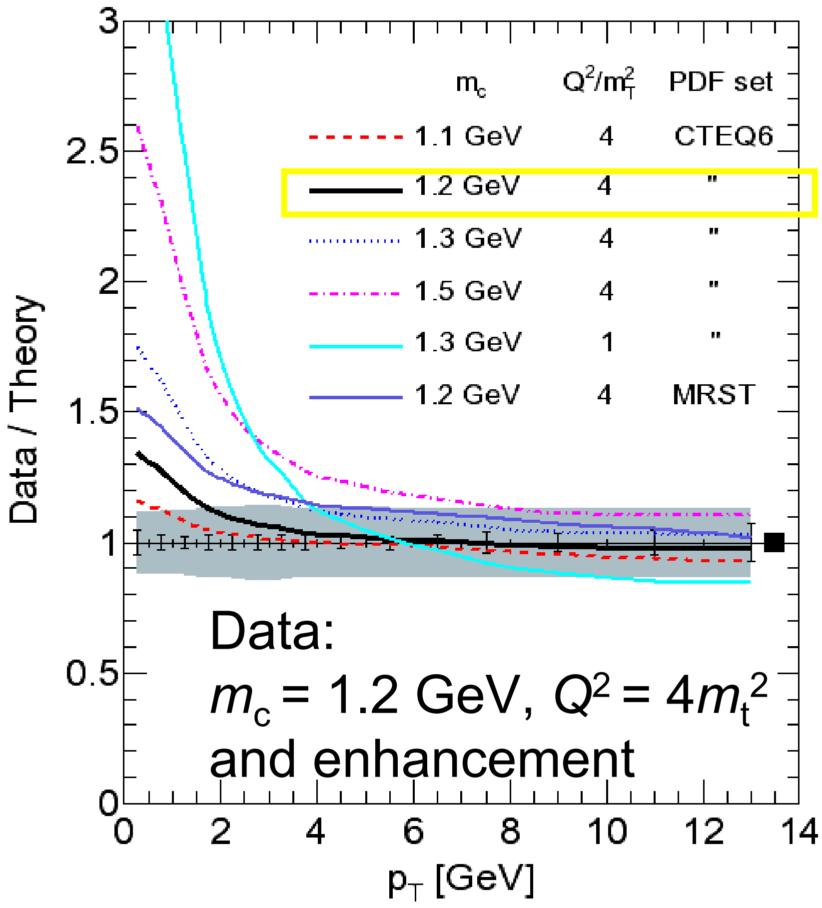
inner bars: statistical
shaded band: systematic

$d\sigma(D^0)/dy$ for
$|y| < 1$ and $p_t > 0.5$ GeV/c

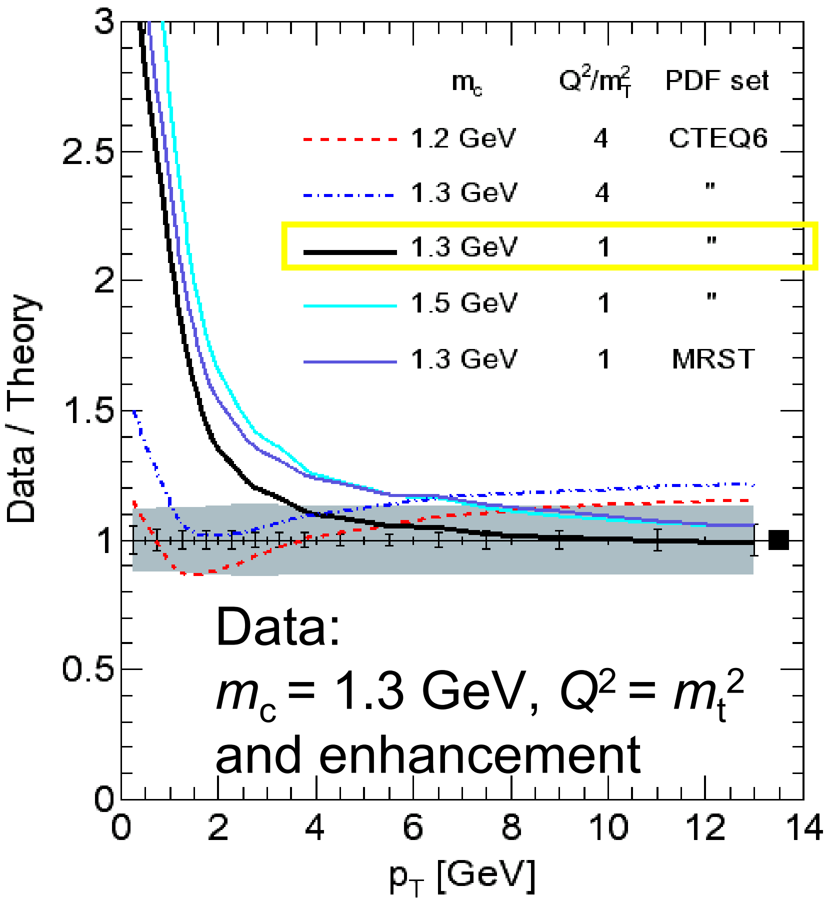
statistical error = **3 %**
systematic error = **14 %**
from beauty = 8 %
MC corrections = 10%
B.R. = 2.4 %
σ_{pp}^{inel} (TOTEM) = 5 %

How to detect the enhancement?

- The idea is that the effect (**enh. only at very low p_t**) cannot be mimicked by NLO pQCD
- In practice: consider ratio “Data/Theory” for all reasonable choices of Theory parameters



Data:
$m_c = 1.2$ GeV, $Q^2 = 4m_t^2$
and enhancement



Data:
$m_c = 1.3$ GeV, $Q^2 = m_t^2$
and enhancement

Conclusions

- Nonlinear effects in gluon evolution imply, at LO, an enhanced (w.r.t. DGLAP based predictions) low-p_t charm production in pp at LHC

- The enhancement depends strongly on the choice of the pQCD scale, and is ~50% in the pessimistic case

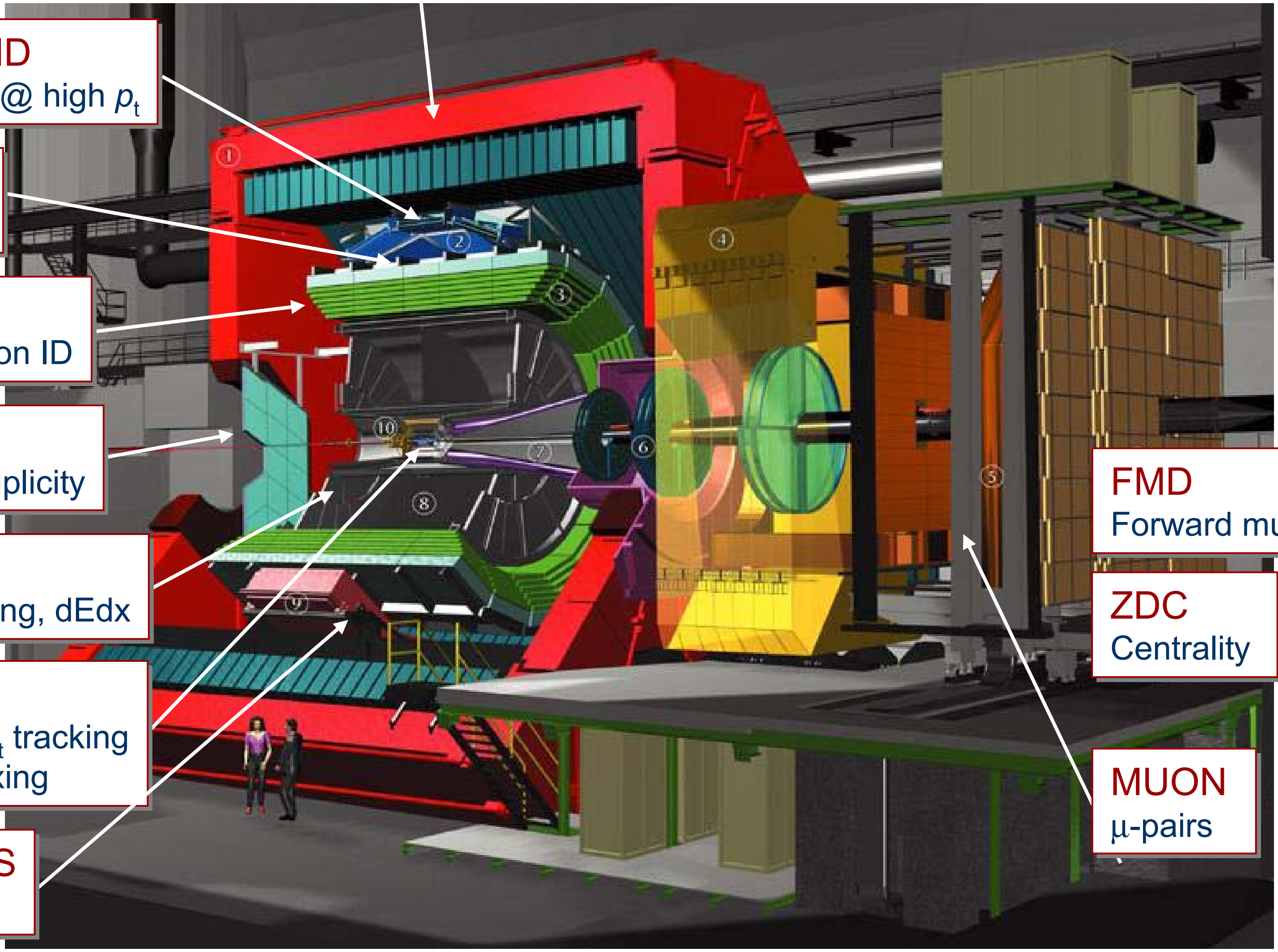
- The enhancement survives hadronization to D mesons

- ALICE can measure D production in pp for $0<p_t<15$ GeV/c

- The enhancement seems to be detectable, as it cannot be mimicked by “playing” with pQCD parameters

Back-up slides

ALICE detector



L3 Magnet
B < 0.5 T: 0.2 T low p_t acceptance, 0.5 T p_t resolution at high p_t

HMPID
RICH @ high p_t

TOF
PID

TRD
Electron ID

PMD
γ multiplicity

TPC
Tracking, dEdx

ITS
Low p_t tracking
Vertexing

PHOS
γ,π^0

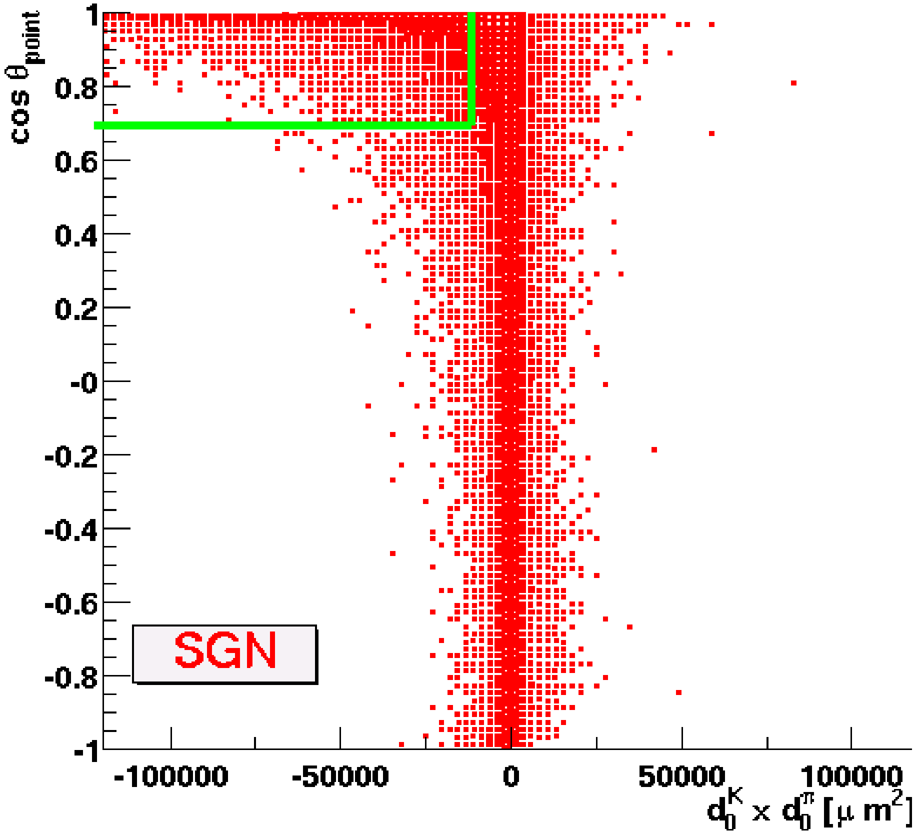
FMD
Forward multiplicity

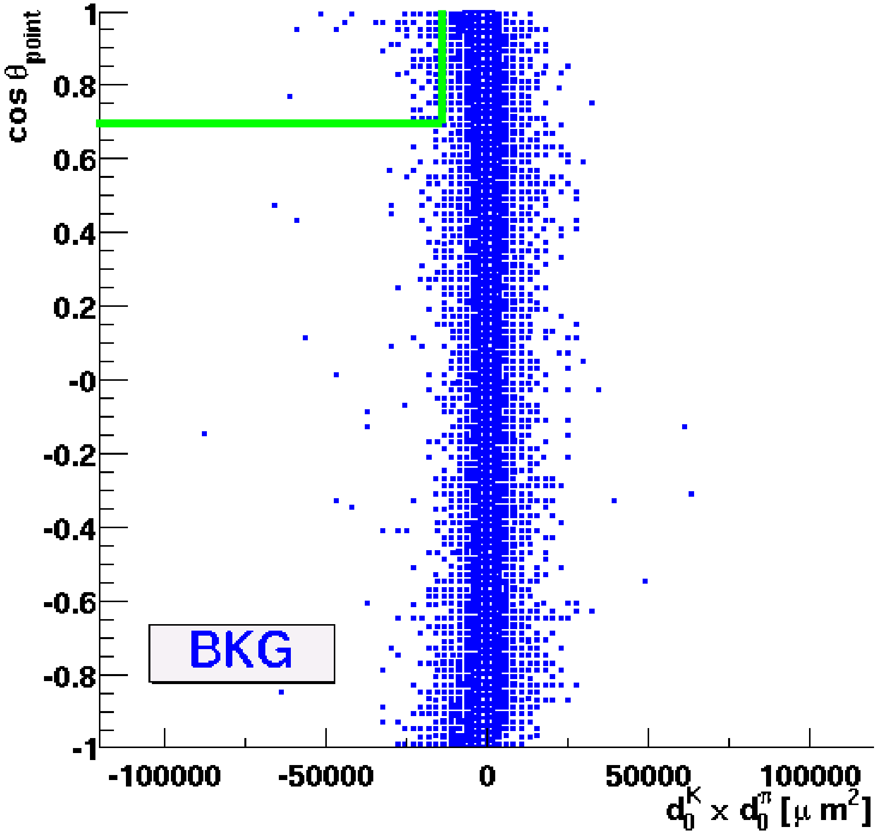
ZDC
Centrality

MUON
μ-pairs

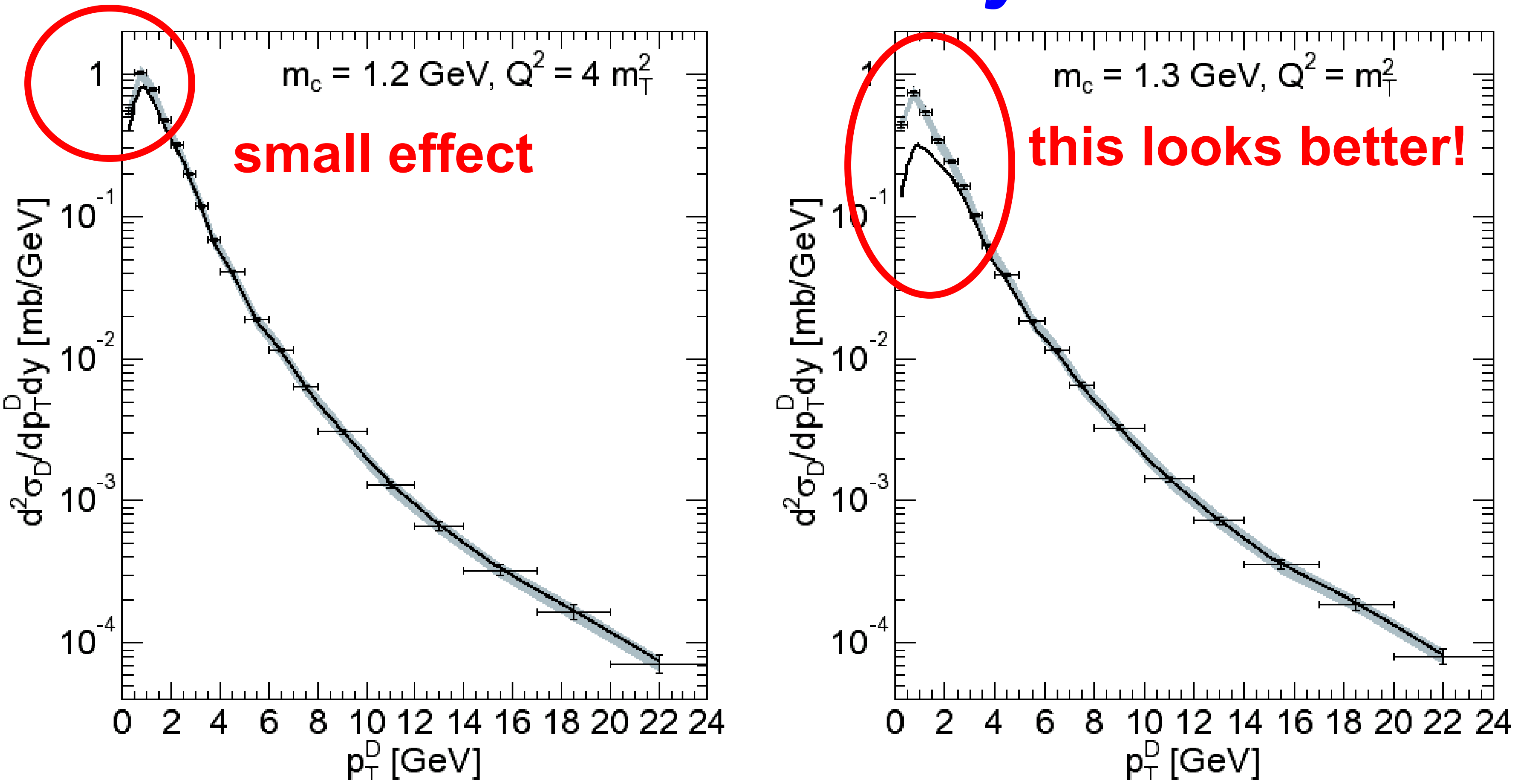
$D^0 \rightarrow K^-\pi^+$: *Selection of D^0 candidates*

- **Main selection: displaced-vertex selection**
  - pair of tracks with **large impact parameters**
  - **good pointing** of reconstructed D^0 momentum to the primary vertex





How do nonlinear effects compare to ALICE sensitivity?



! assuming same enhancement at NLO as at LO !

A.D., R.Vogt, M.Bondila, K.J.Eskola and V.J.Kohlinen, hep-ph/0403098