Beauty detection via displaced electrons with ALICE at LHC

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Contents

- **Beauty production as a test for QCD**
  - Tevatron experience
  - Theoretical predictions for LHC

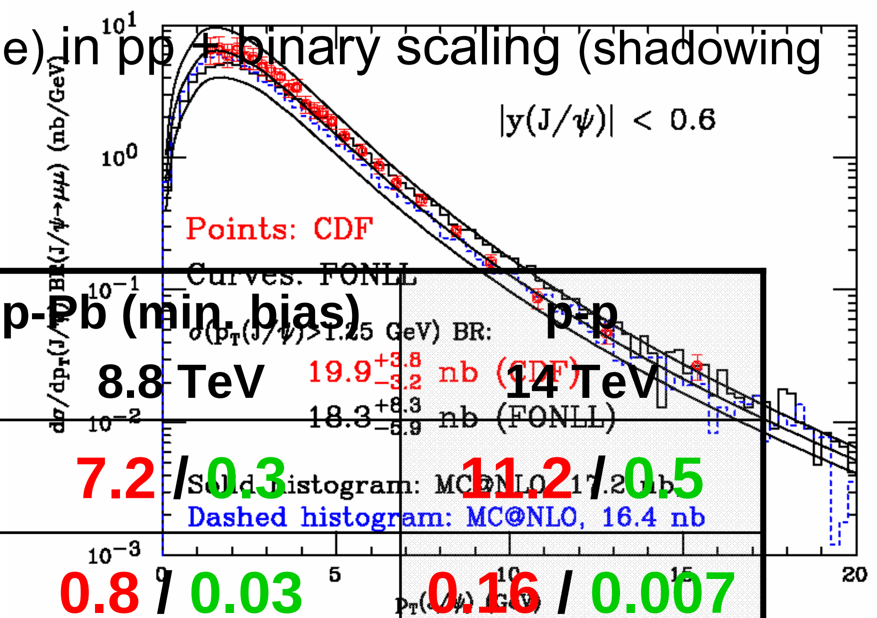
- **Measurement of beauty in ALICE with the central barrel**
  - ALICE layout
  - Experimental strategies
  - Results of the simulations

Heavy-quark production

- **p-p:** Important test of pQCD (LHC: **new energy domain**)
- **Remember the “15-years saga of b production at Tevatron”***
- **Baseline predictions:** NLO (MNR code) in pp + binary scaling (shadowing included for PDFs in the Pb)
- **ALICE baseline** for charm / beauty:

B production at Tevatron (1.96 TeV) is well described by FONLL

Cacciari, Frixione, Mangano, Nason and Ridolfi, JHEP0407 (2004) 033



system : $\sqrt{s_{NN}}$:	**Pb-Pb (0-5% centr.) 5.5 TeV**	**p-Pb (min. bias) 8.8 TeV**	**p-p 14 TeV**
$\sigma_{NN}^{Q\overline{Q}}$ [mb]	**4.3 / 0.2**	**7.2 / 0.3**	**11.2 / 0.5**
$N_{tot}^{Q\overline{Q}}$	**115 / 4.6**	**0.8 / 0.03**	**0.16 / 0.007**

Theoretical uncertainty of a factor 2—3 (next slide)

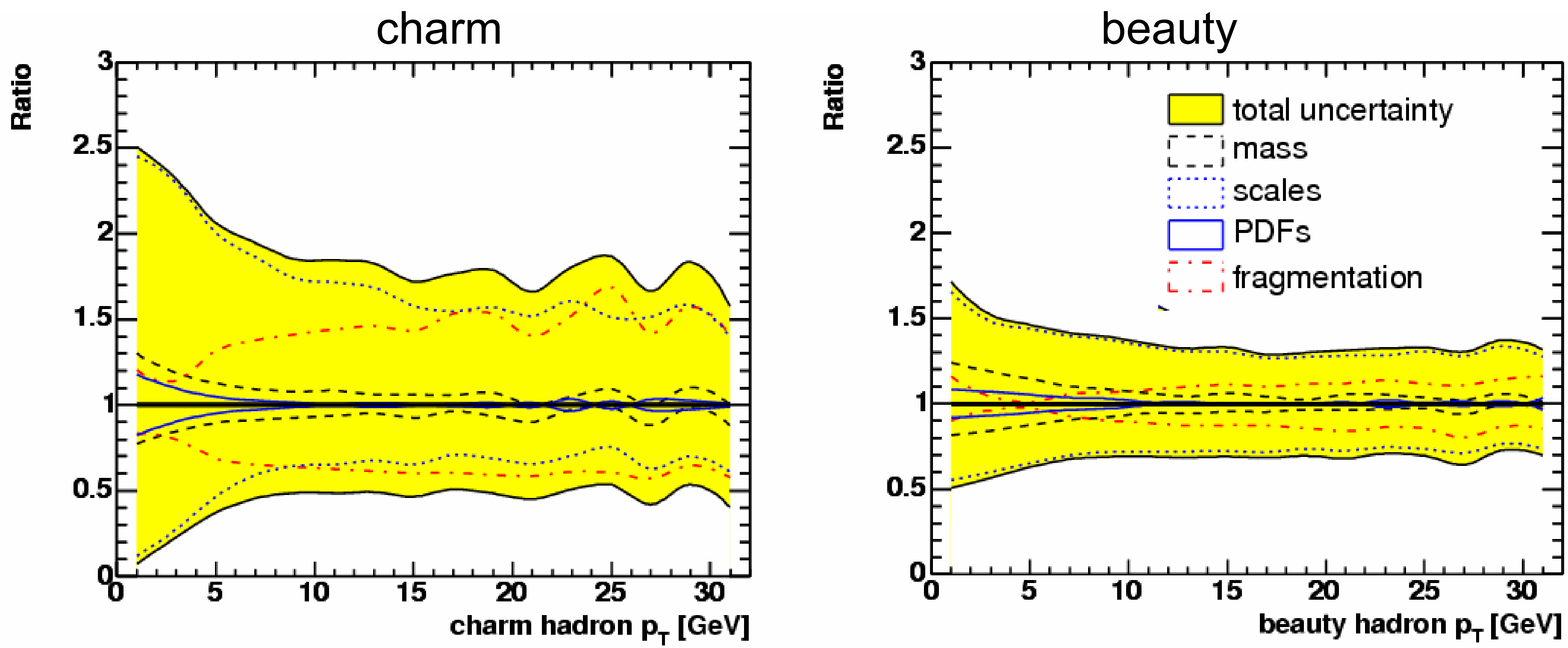
* M.Mangano
MNR code: Mangano, Nason, Ridolfi, NPB373 (1992) 295.

Theoretical Uncertainties

p-p @ 14 TeV

Proceedings HERA-LHC Workshop (2005)

CERN/LHCC 2005-014
hep-ph/0601164



$1.3 < m_c < 1.8$ GeV $\quad 0.5 < \mu_{F,R} / m_T < 2 \quad 0.002 < \varepsilon_c < 0.11$

$4.5 < m_b < 5.0$ GeV $\quad 0.5 < \mu_F / \mu_R < 2 \quad 0.0002 < \varepsilon_b < 0.004$

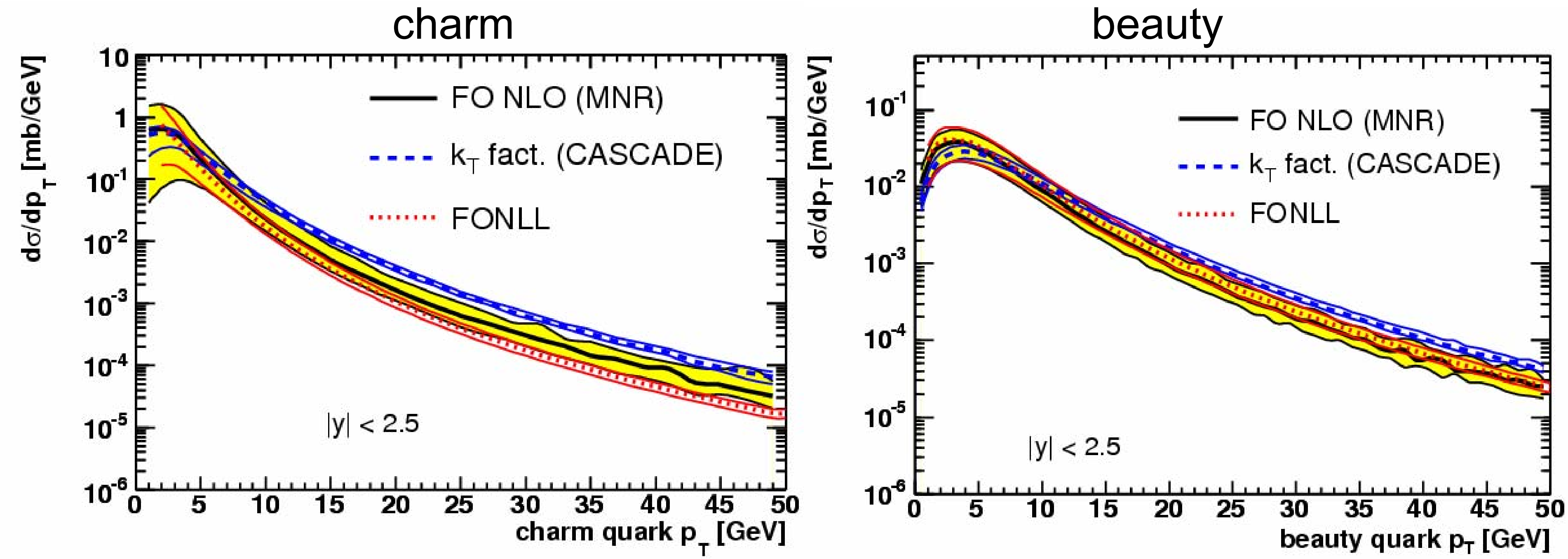
PDFs : CTEQ4, CTEQ5, CTEQ6, MRST2001

MNR code: Mangano, Nason, Ridolfi, NPB373 (1992) 295.

Model comparisons

Proceedings HERA-LHC Workshop (2005)

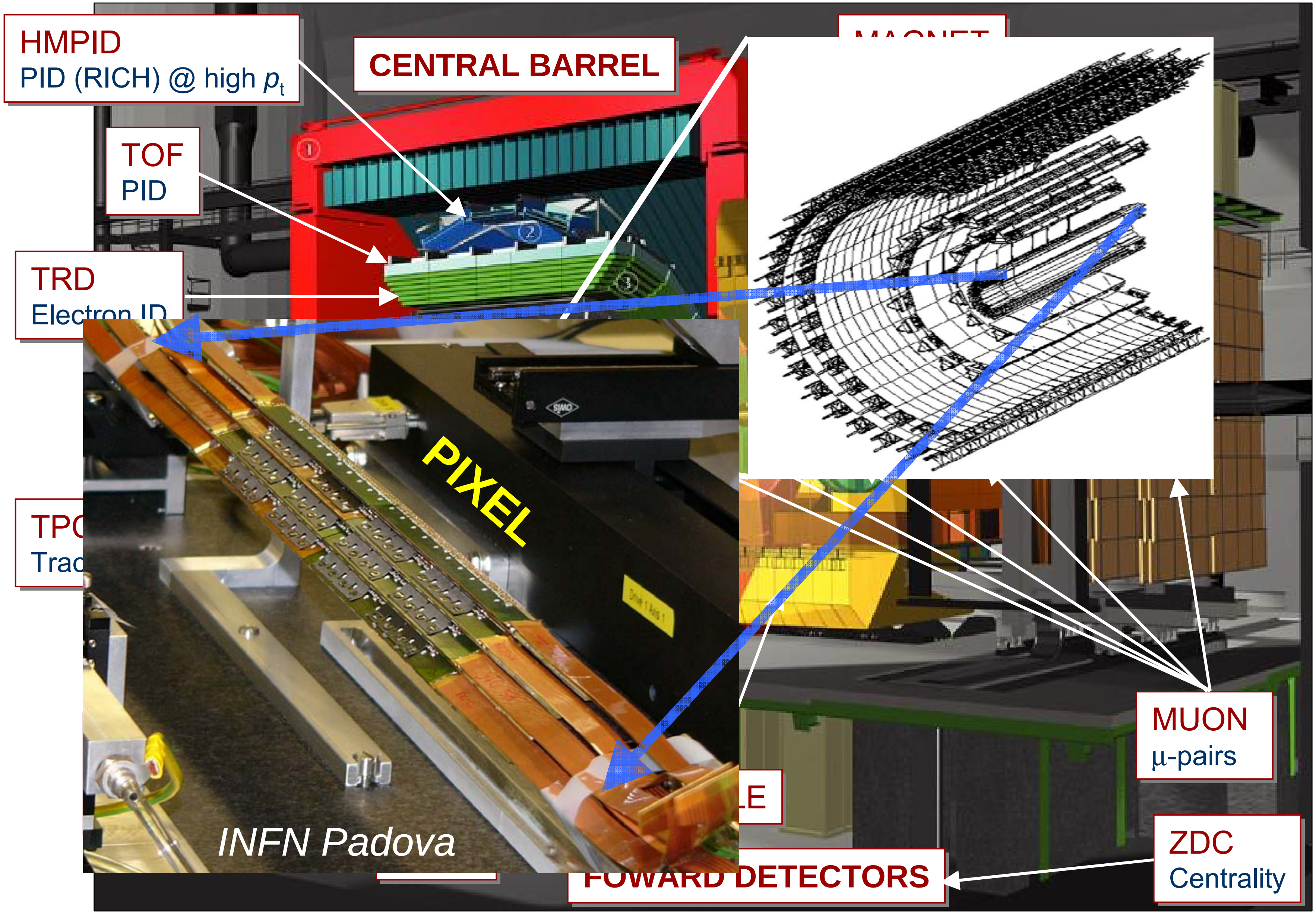
CERN/LHCC 2005-014
hep-ph/0601164



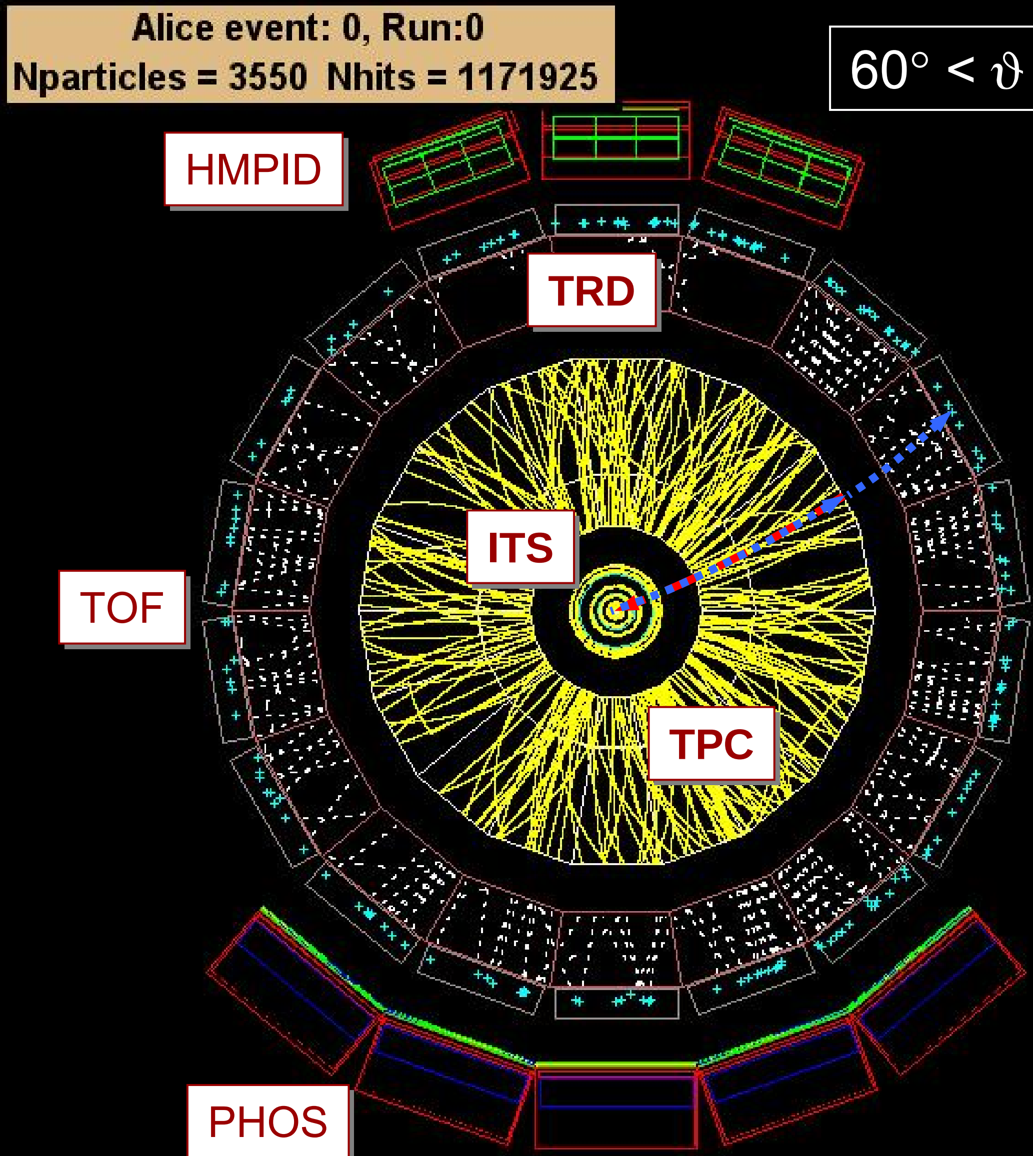
⇨ Good agreement between FO NLO and FONLL

⇨ k_T factorization (CASCADE) higher at large p_T

ALICE detector



Tracking in the Central Barrel



$60° < \vartheta < 62°$

Pb+Pb @ 5.5 TeV

Kalman Filter

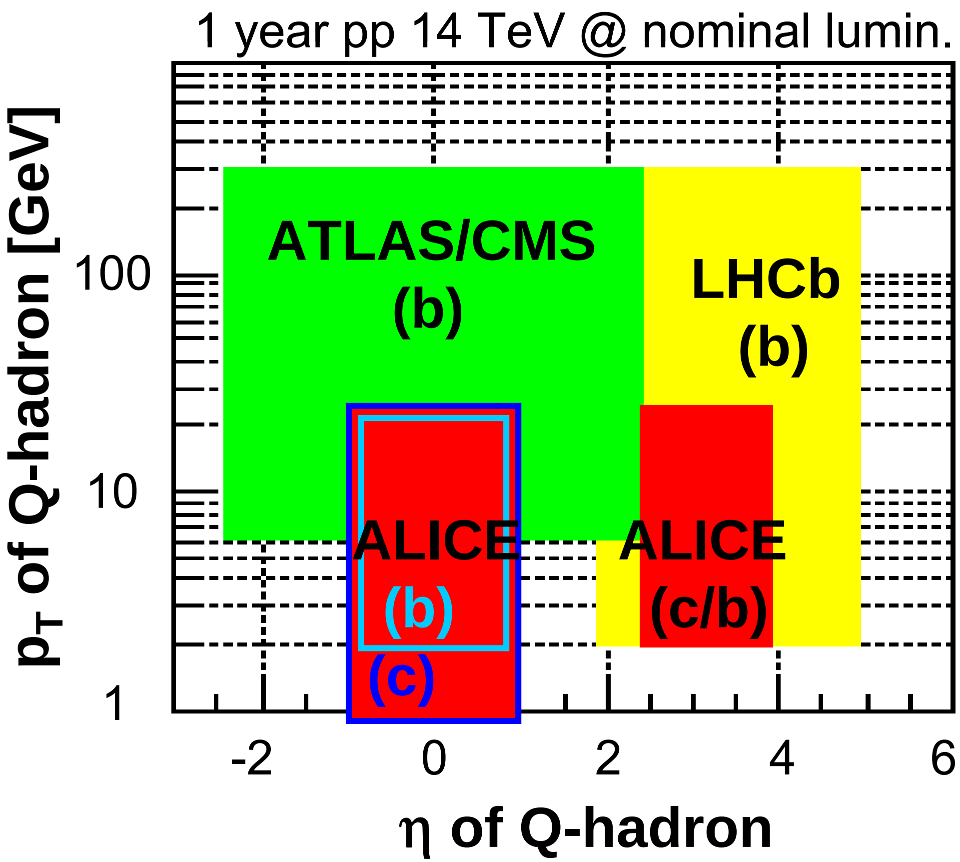
Seeds in outer TPC

Tracking toward ITS

Backpropagation to TOF

ALICE heavy-flavour potential

- ALICE combines **electronic** ($|\eta|<0.9$), **muonic** ($-4<\eta<-2.5$), **hadronic** ($|\eta|<0.9$) channels
- ALICE covers **low-p_T region**
- ALICE covers **central and forward regions**
- **Precise vertexing** in the central region to identify D ($c\tau$ ~ 100-300 μm) and B ($c\tau$ ~ 500 μm) decays



Semi-electronic channel

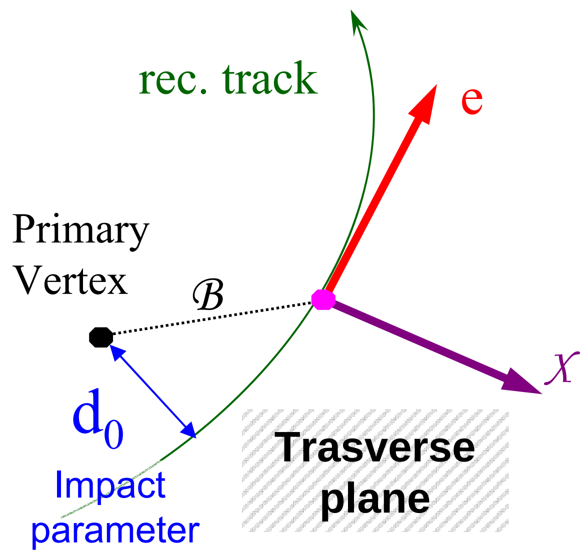
B → e + X

Branching Ratio = **11%**

from b → B → e+X

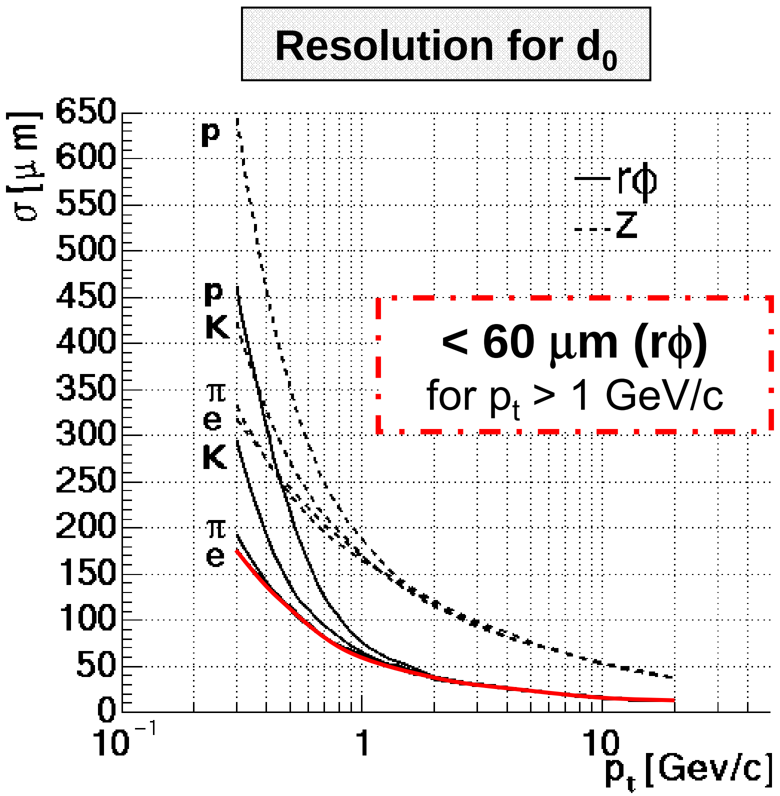
+10% from b → B → D → e+X

Collision	**pp** (14 TeV)		**PbPb** (5.5 TeV)	
Product	b-bbar pairs	B-mesons with an electron in acceptance	b-bbar pairs	B-mesons with an electron in acceptance
Yield	0.0072	0.00076	4.56	0.48



cτ D⁰ 123 μm

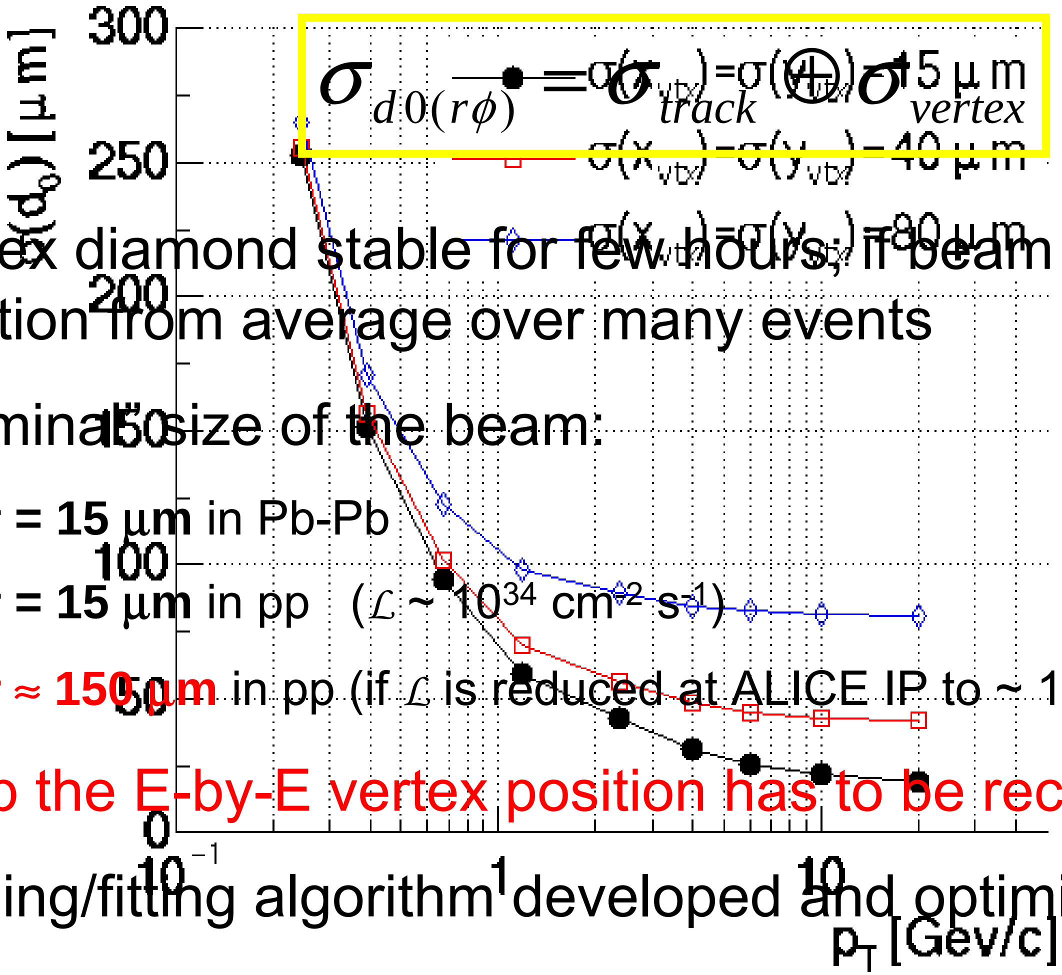
cτ B ~500 μm



Detectors: ITS + TPC + TRD

The role of the primary vertex

σ_{d0}



- Vertex diamond stable for few hours; if beam focused, precise vertex position from average over many events
- "Nominal" size of the beam:

  σ = 15 μm in Pb-Pb

  σ = 15 μm in pp ($\mathcal{L} \sim 10^{34}$ cm^{-2} s^{-1})

  σ ≈ 150 μm in pp (if $\mathcal{L}$ is reduced at ALICE IP to ~ 10^{30} cm^{-2} s^{-1})
- In pp the E-by-E vertex position has to be reconstructed using tracks
- Finding/fitting algorithm developed and optimized

First Approach: DONE (but not shown here)

A.Dainese and M.Masera, ALICE-INT-2003-027.

Optimize vertex reconstruction for best separation of beauty-decay e's

Beauty Signal

Heavy-quark decays:

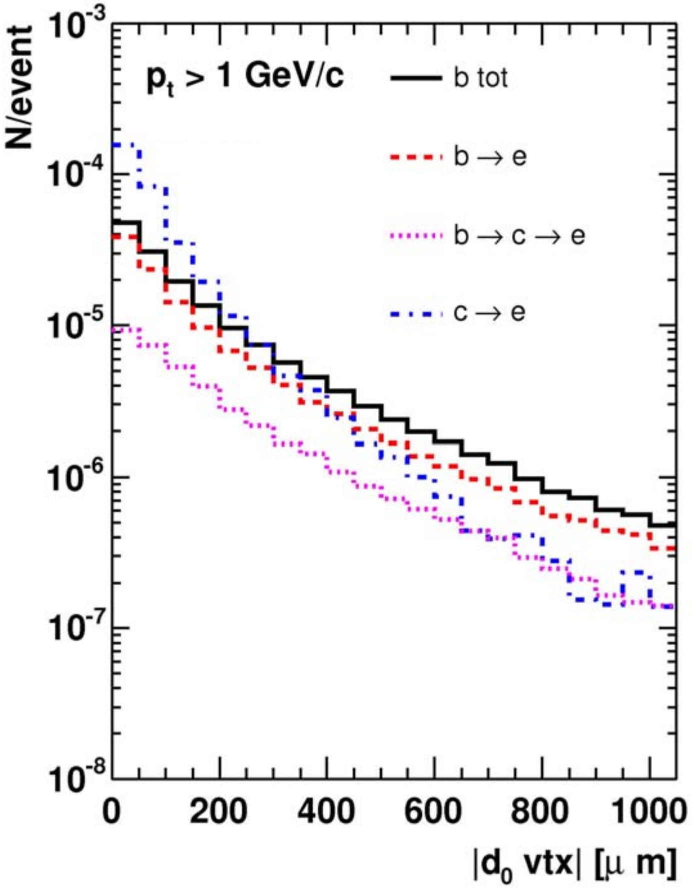
- b→B→e
- b→B→D→e
- c→D→e

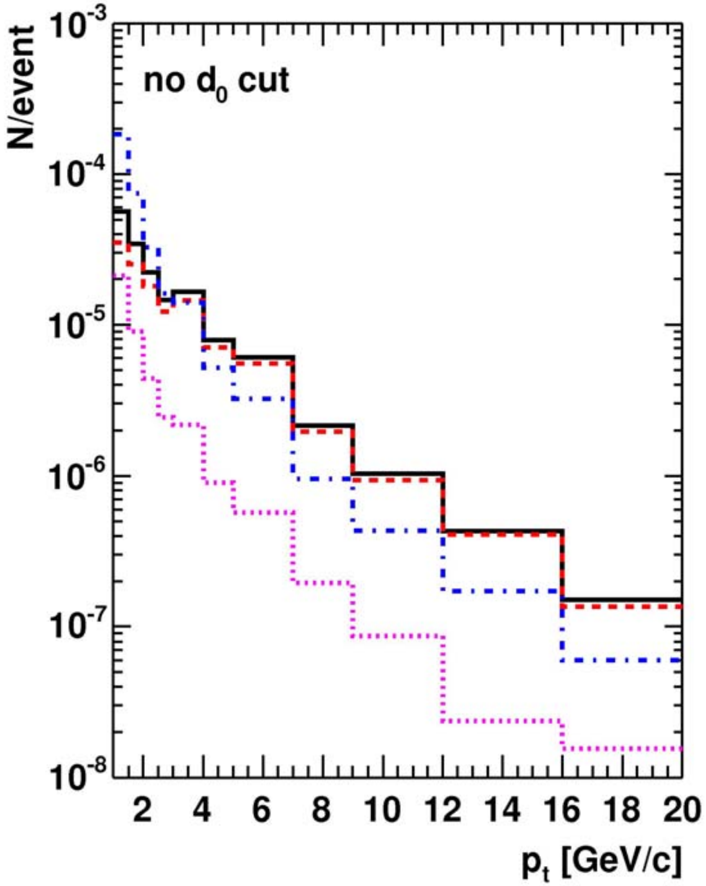
} **beauty**

} **charm** (background)

p-p @ 14 TeV

Simulation:
Pythia + H.F. tuned on MNR* calculations

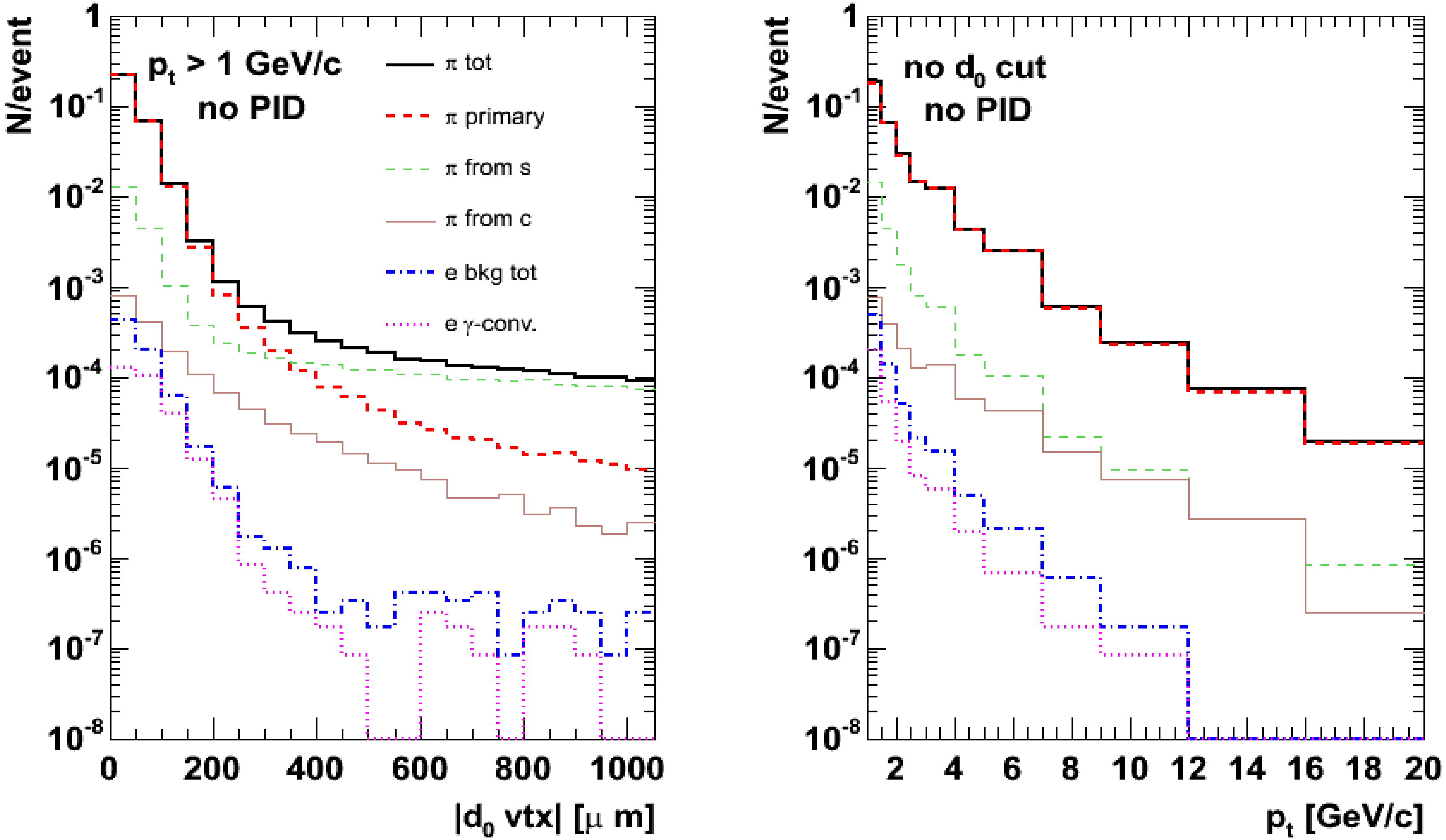




*MNR code: Mangano, Nason, Ridolfi, NPB373 (1992) 295.

Other background sources

1. **Charged Pions** mis-identified as electrons
2. Photon conversions ($\gamma \rightarrow e^+e^-$) in the beam pipe and inner layers
3. Decays of light mesons and Dalitz decays (mostly π^0)



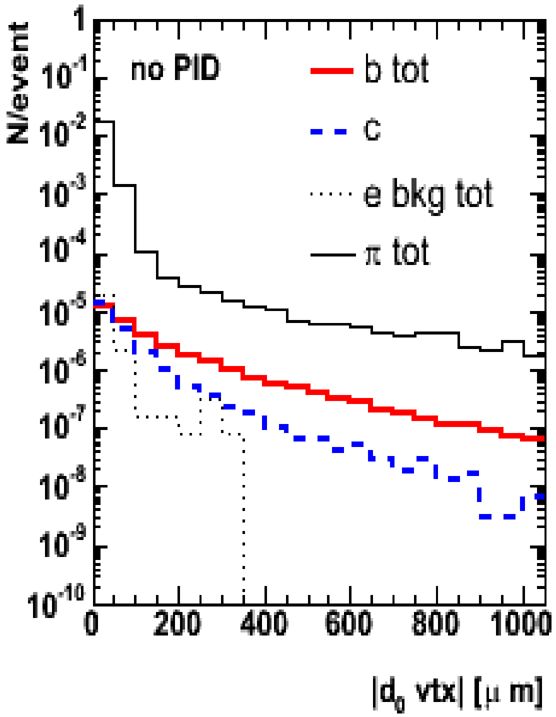
Electron Identification (TPC+TRD)
(separation between e/π)

→

Kinematical Cuts
(in d_0 according to the p_t bin)

→

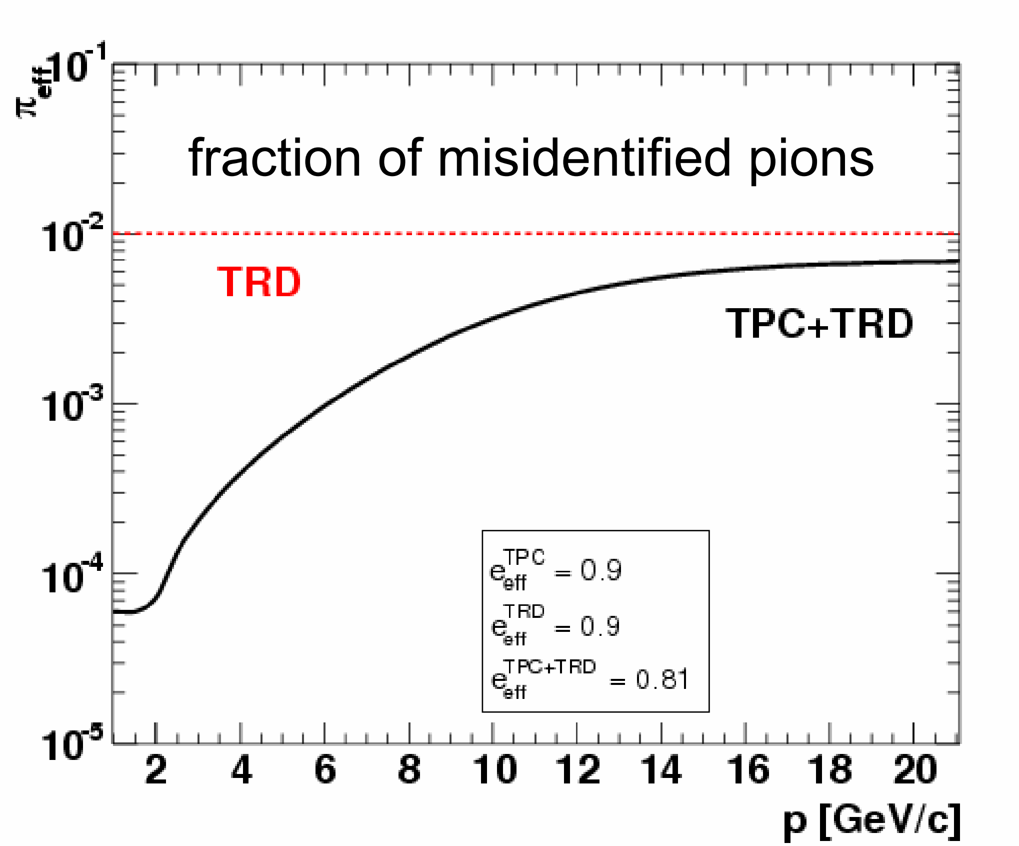
Subtraction of residual background
(small)



Electron Identification

Combined info from TRD (trans. rad.) and TPC (dE/dx)

- TRD rejects 99% of the $\pi^{\pm}$ and ALL heavier hadrons (p_t > 1 GeV/c)
- TPC further rejects residual pions (up to 99% at low p)
- About 20% of electrons rejected



Cross Section

In a given p_t-bin we get N “electrons”: $N = N_b + N_c + N_{bkg}$

1. We subtract the contribution from charm: $N - N_c$

Charm calculated from D^0 measurement

2. We subtract the contribution from background: $N_b = (N - N_c) - N_{bkg}$

Estimated from measured pions dN/dp_t plus MC (including conversions)

3. We correct for acceptance/efficiency: $dN_b^{corr}/dy = (N_b / \varepsilon)$

Calculated with MC techniques

4. We multiply by the inelastic pp cross section: $d\sigma_e/dy = \sigma_{pp} \cdot dN_b^{corr}/dy$

Cross section measured at LHC

Errors

Statistical $\frac{\sigma_{N_b}}{N_b} = \frac{\sqrt{N_b + N_c + N_{bkg}}}{N_b}$

d$_0$ cut affects

we want a cut that minimizes the error

Systematic

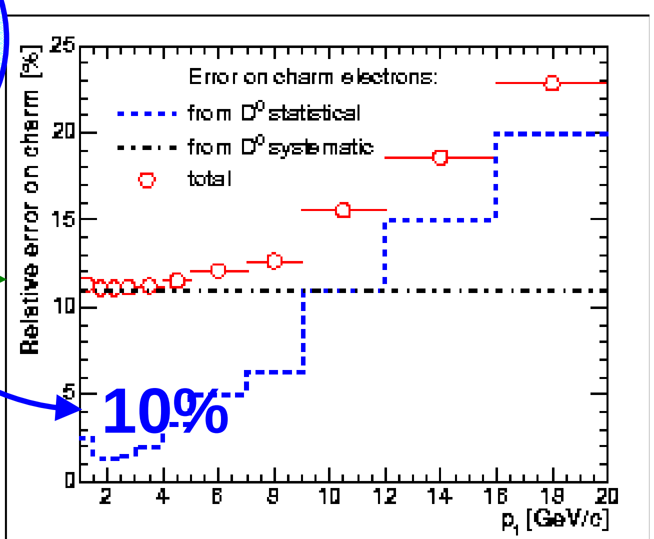
Error from acceptance effect corrections (via MC):

10% (in principle p_t-dependent)

Error from subtractions: $\frac{\sigma_{N_b}}{N_b} = \frac{\sigma_{N_c}}{N_c}\frac{N_c}{N_b} \oplus \frac{\sigma_{N_{bkg}}}{N_{bkg}}\frac{N_{bkg}}{N_b}$

Rel. err. on **bkg**:

Rel. err. on **charm**:



Error from inelastic cross section:

5% (p_t-independent)

Cut: $|d_0|>|d_0|^{MIN}$

Systematic error:

prefers tight cut (high signal purity)

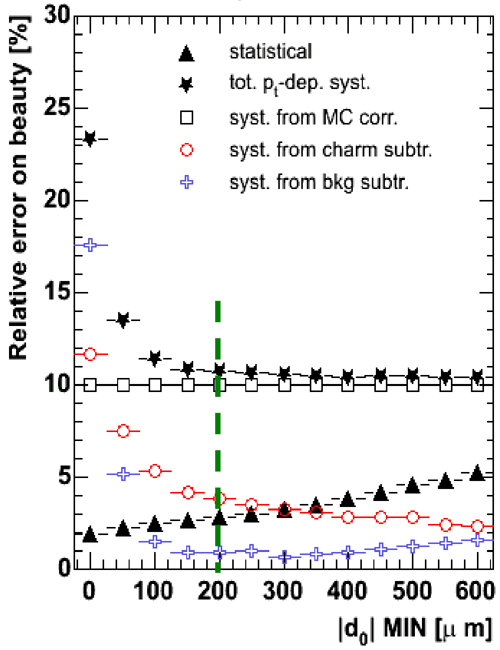
dominates at low p_t

Statistical error:

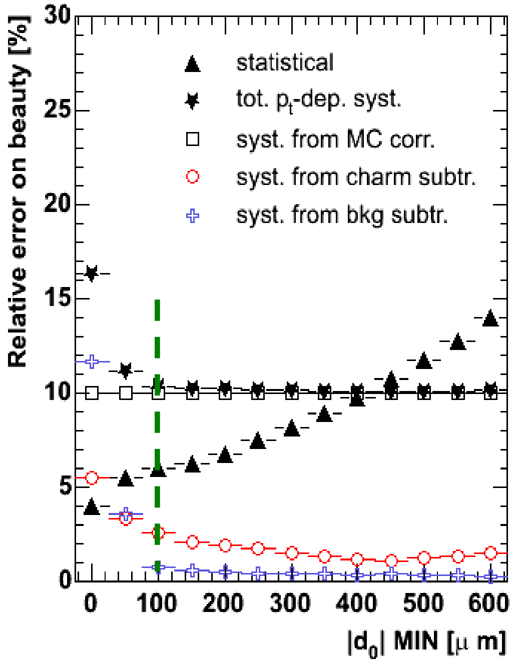
prefers loose cut (small d_0 MIN)

dominates only at high p_t

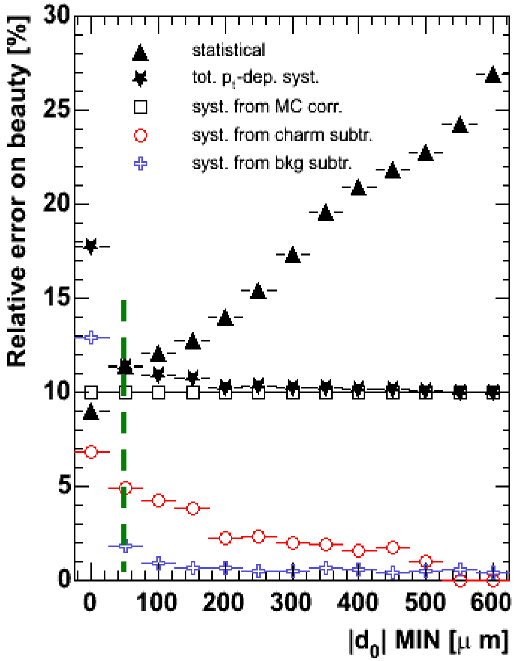
$2.5 < p_t < 3$ GeV/c



$7 < p_t < 9$ GeV/c



$12 < p_t < 16$ GeV/c

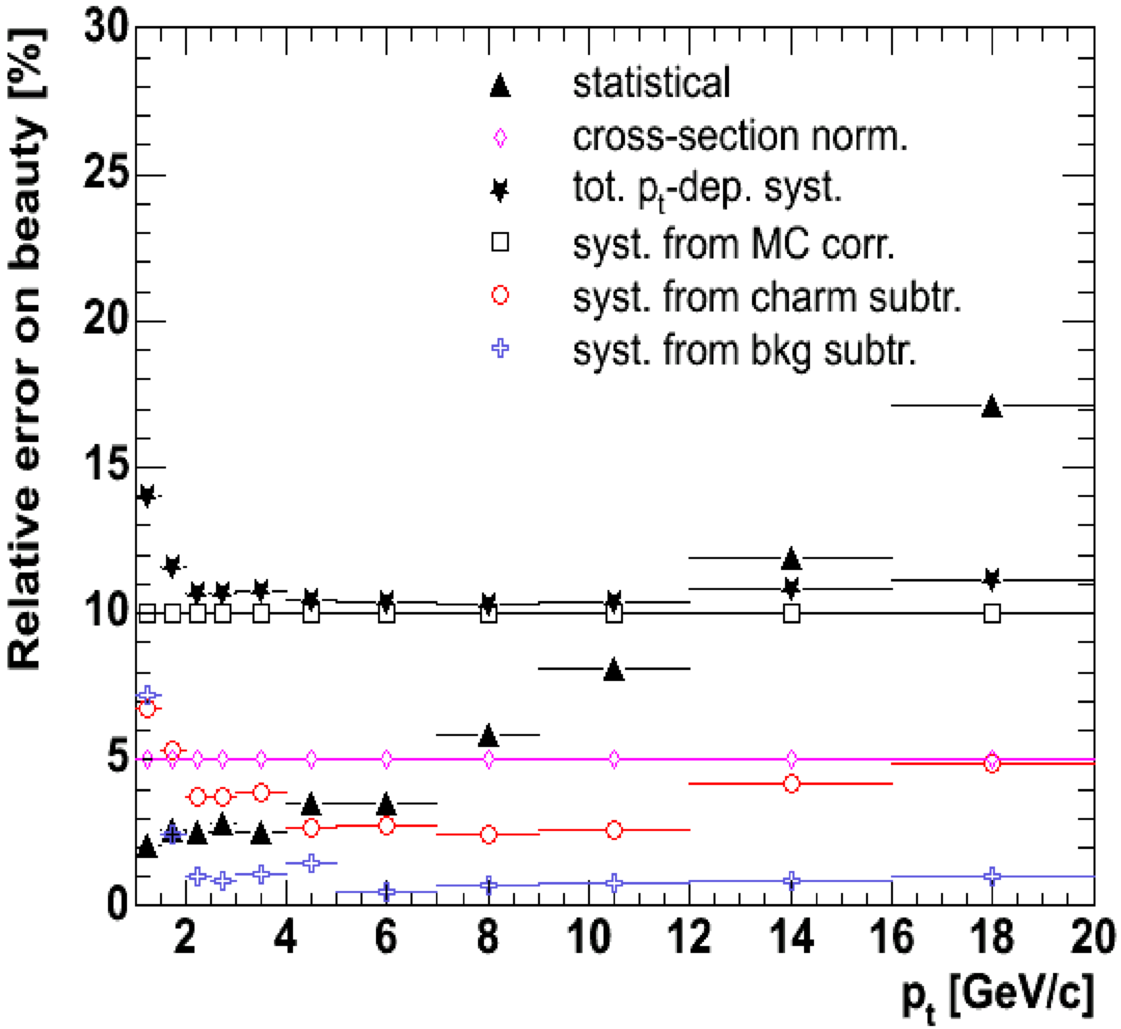


Statistics summary

p_t bin [GeV/c]	$|d_0|$ cut [μm]
1.0 – 1.5	400
1.5 – 2.0	400
2.0 – 2.5	300
2.5 – 3.0	200
3.0 – 4.0	150
4.0 – 5.0	150
5.0 – 7.0	100
7.0 – 9.0	100
9.0 – 12.0	100
12.0 – 16.0	50
16.0 – 20.0	50

10^9 pp events

(1 year of nominal ALICE luminosity)

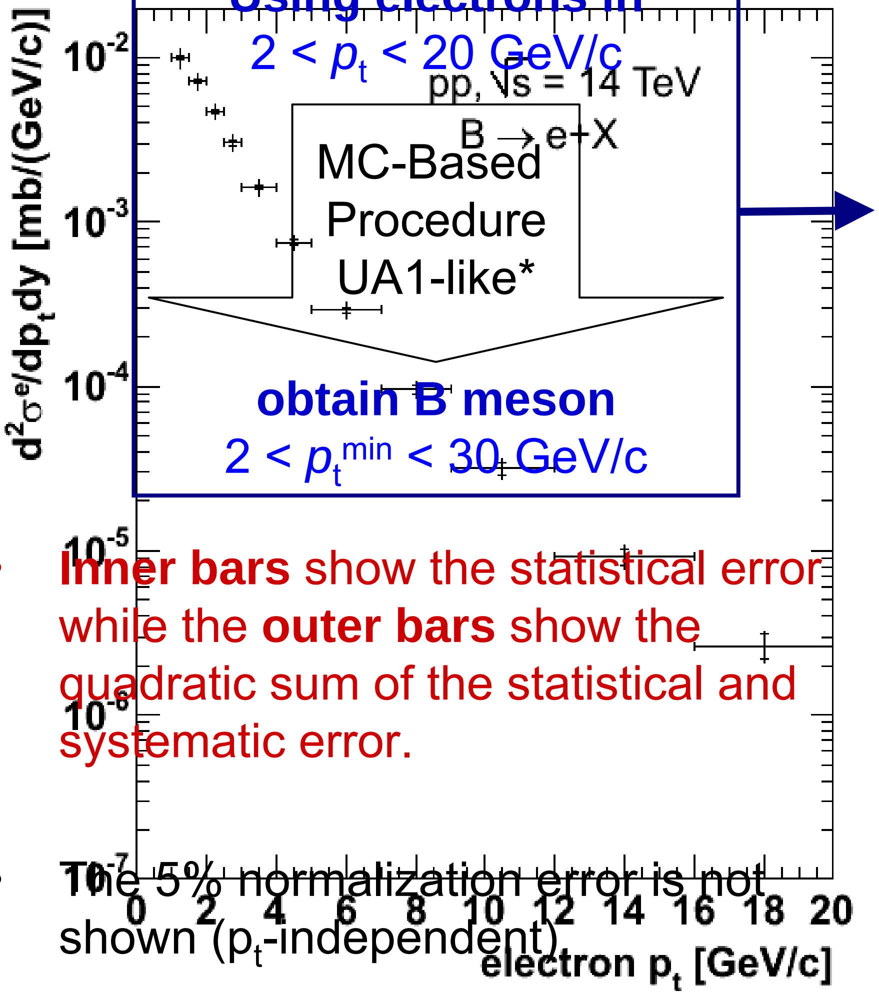


Cross Section

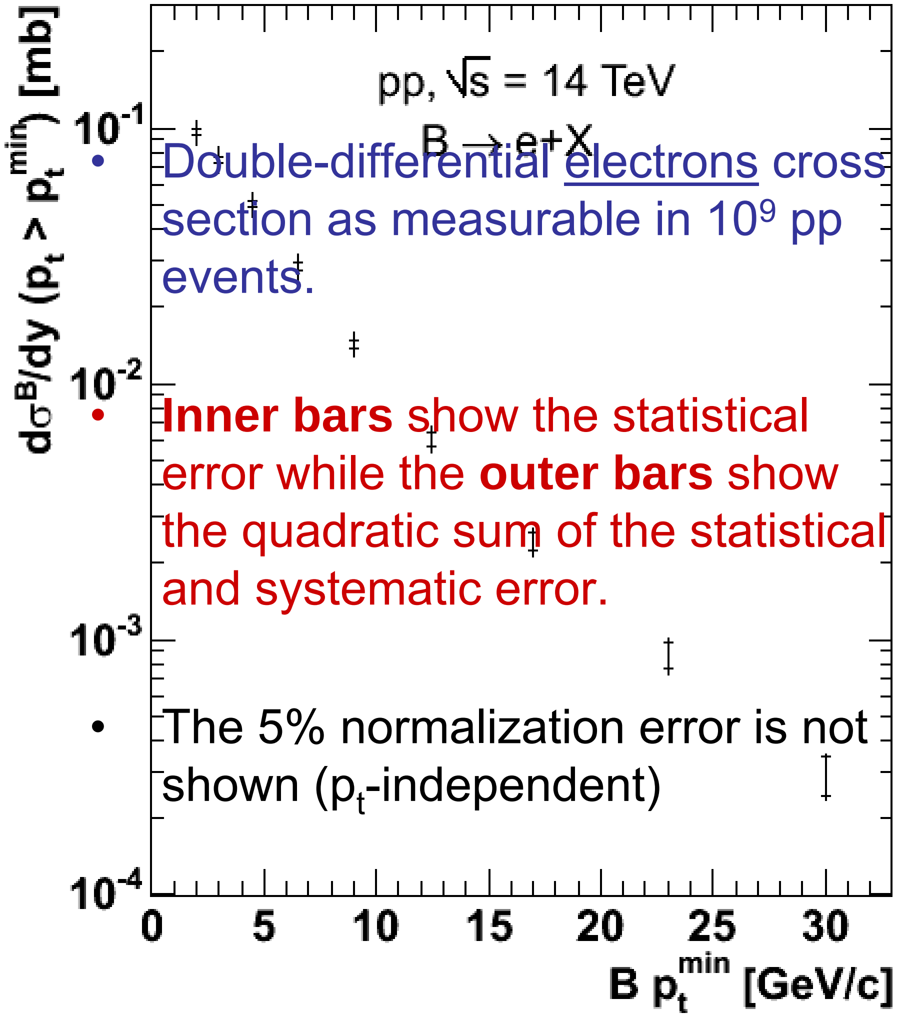
Using electrons in
$2 < p_t < 20$ GeV/c

MC-Based
Procedure
UA1-like*

obtain B meson
$2 < p_t^{min} < 30$ GeV/c



- **Inner bars** show the statistical error while the **outer bars** show the quadratic sum of the statistical and systematic error.
- The 5% normalization error is not shown (p_t-independent).

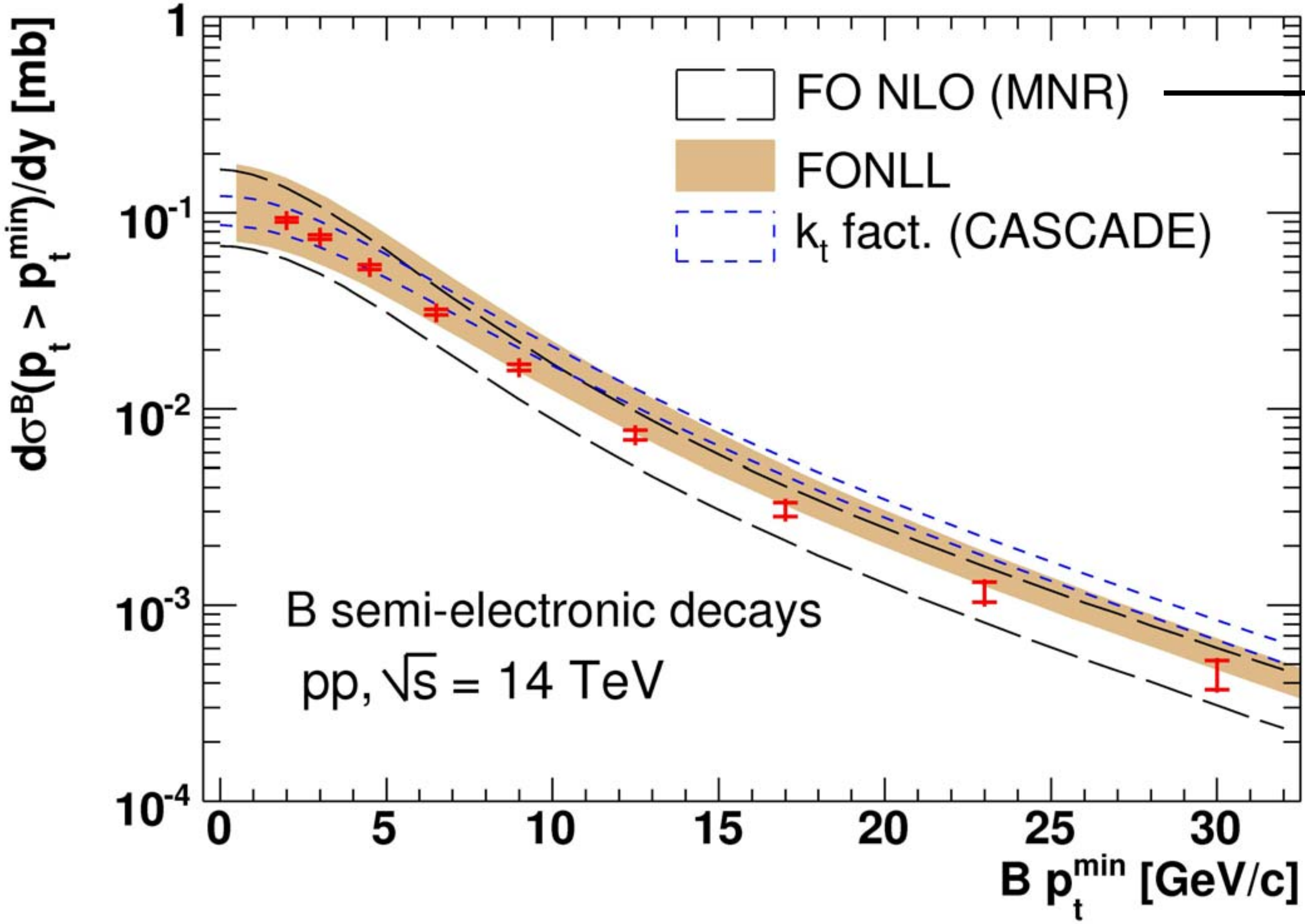


- Double-differential electrons cross section as measurable in 10^9 pp events.
- **Inner bars** show the statistical error while the **outer bars** show the quadratic sum of the statistical and systematic error.
- The 5% normalization error is not shown (p_t-independent)

*P. Crochet, R. Guernane, A. Morsch and E. Vercellin, ALICE Internal Note ALICE-INT-2005-018 (2005).

Differential B-mesons cross section

10^9 pp events



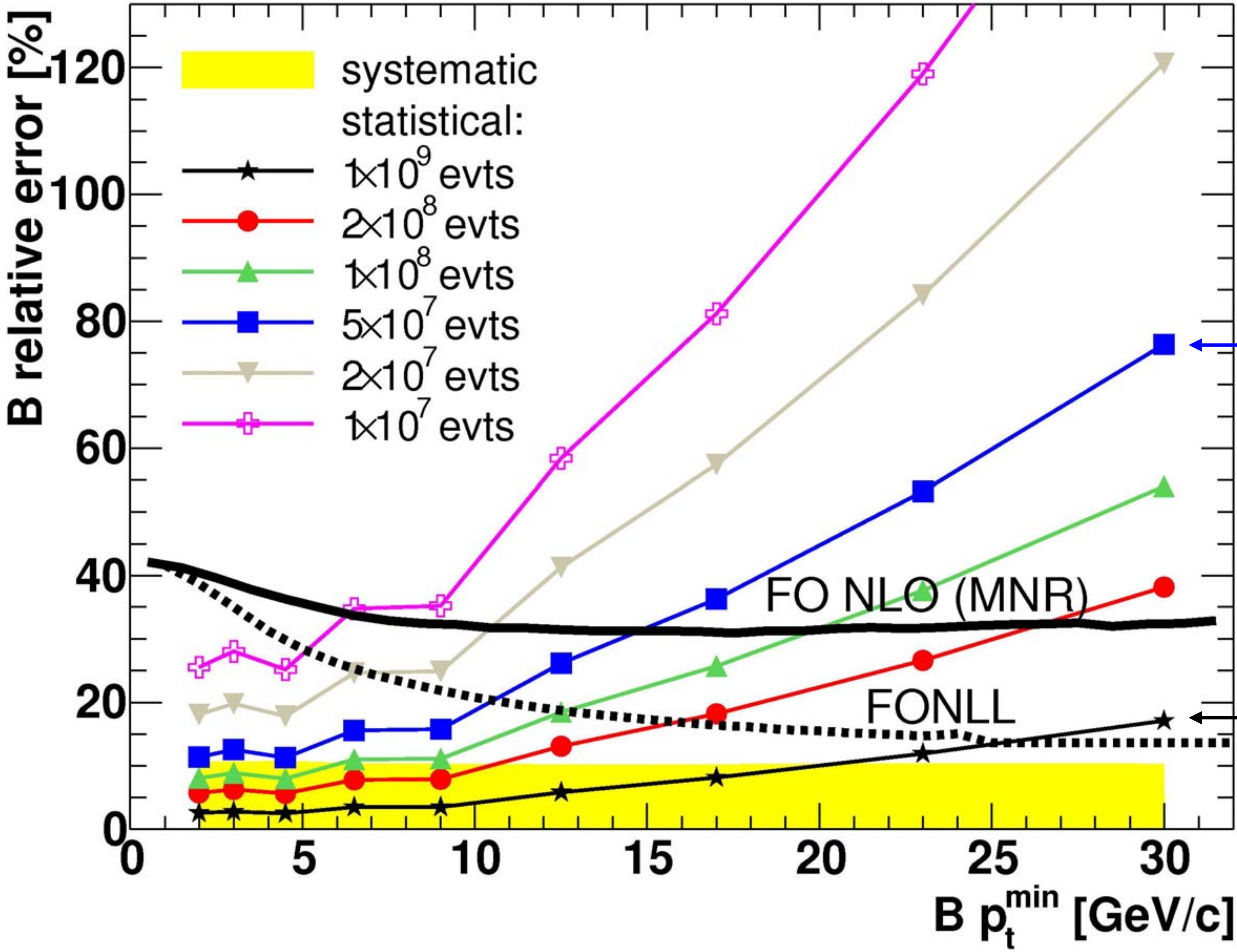
Baseline for this study

Red bars: results of this study

Theoretical predictions rescaled from |y|<2.5 to |y|<1

From electrons in 2 < p_t < 20 GeV/c, B mesons in 2 < p_t^{min} < 30 GeV/c

Perspectives for the initial runs



Full setup
(ITS+TPC+TRD)

~1 nominal ALICE-month

1 nominal ALICE-year

Conclusions

- **Beauty production in pp at collider energies**
  - Test of pQCD theory
  - Hard-earned success at Tevatron
  - Large uncertainities for predictions at LHC

- **ALICE is equipped for heavy-flavour studies in pp**
  - Using single electrons is just the first/simplest approach
  - Cross section for B mesons: sensitive test for QCD predictions

- **Coming up next**
  - Other approaches (b-tagging of jets, b-decay vertex …)
  - Finalize the method

EXTRA

Luminosity

Design Luminosity in pp @ 14 TeV: $\sim 10^{34}$ cm^{-2} s^{-1} ← Too much! → **Pile-up!**

Max Luminosity $\sim 10^{30}$ cm^{-2} s^{-1} → Solution → **Enlarge the beam size**

$\sim 10^{9}$ events in one LHC-year

Beam Size ~150 μm vs. **cτ D^0** 123 μm and **cτ B** ~500 μm

Main issues:

- We need a good precision on the vertex position for selection of displaced tracks
- We cannot use the nominal vertex position!
- **We must optimize vertex reconstruction using the tracks**

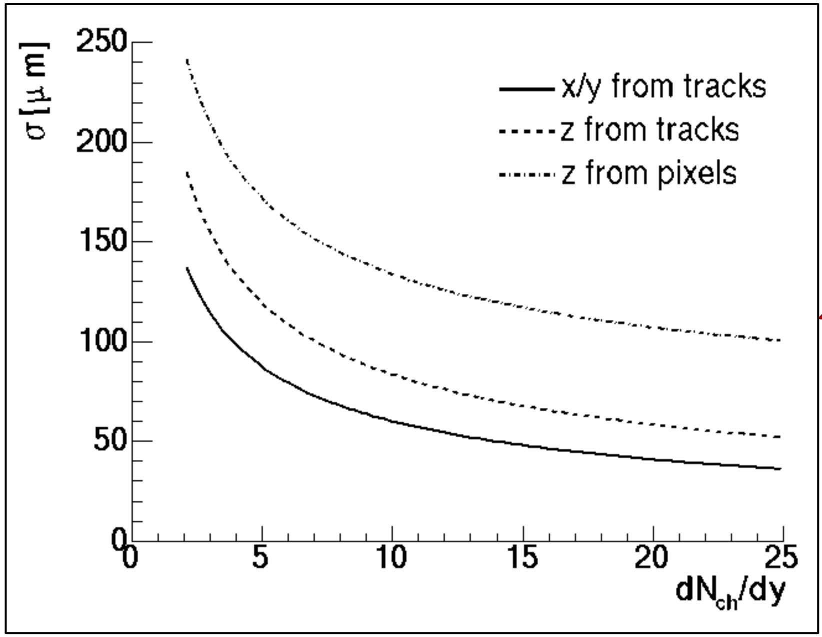
Primary Vertex Reconstruction in pp

Tracking: tracks propagated to the nominal vertex position

Vertex Finding: first estimate using all the pairs of tracks

Vertex Fitting: tracks propagated to the position calculated above, best vertex position from χ^2 minimization

Results (A. Dainese and M. Masera)



Vertex Resolution

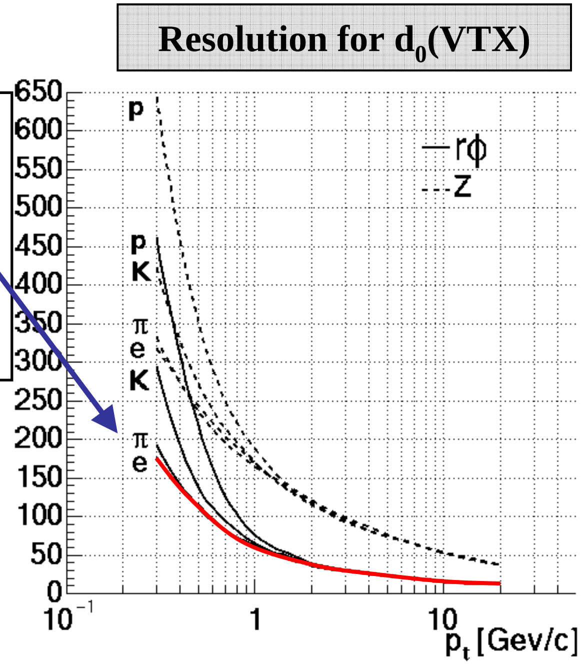
Selecting the Tracks for Vertexing

VTX: vertex from the MC (for comparison only)

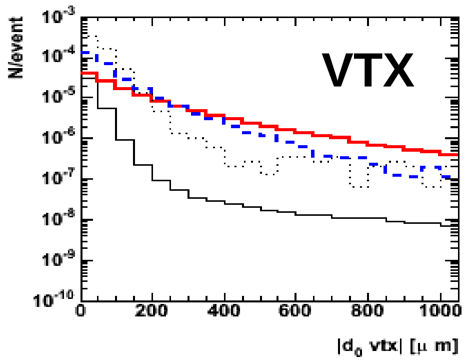
ALL: no selection on the tracks

OTHER: method that uses all tracks save the one for which the impact parameter is being calculated

1σ,3σ,5σ: method that uses all tracks with $d_0 < n\sigma(p_t)$ where σ is the d_0-resolution and d_0 is calculated with respect to the primary vertex with no selection (ALL)

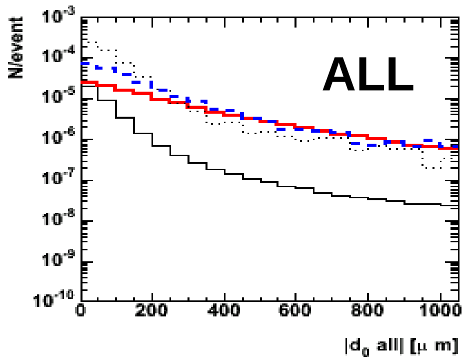


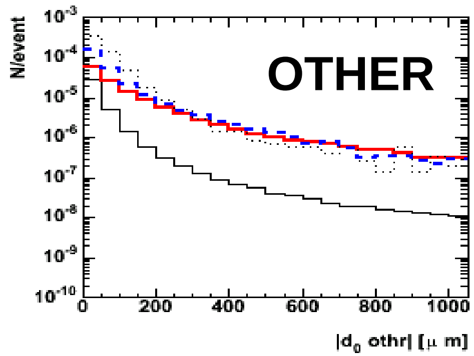
Testing the Methods

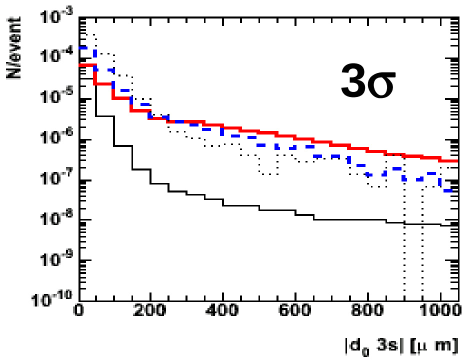


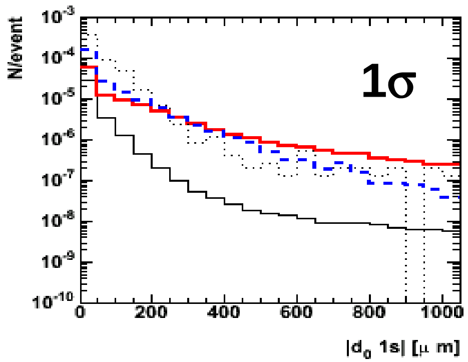
p_t> 1 GeV/c

— b tot
- - c
······ e bkg tot
— π tot





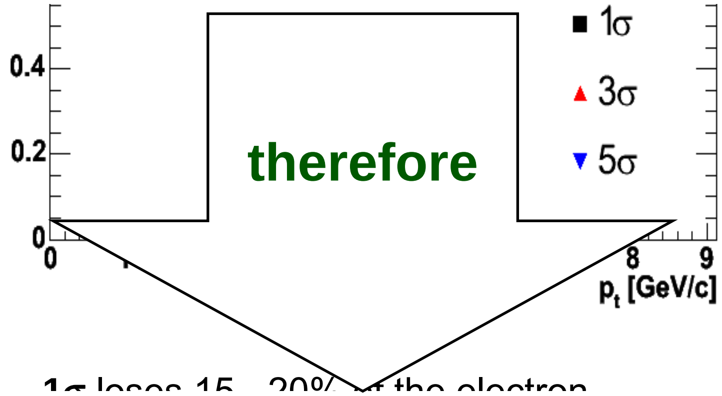




Fraction of Tracks

but …

If an event has less than 3 tracks the primary vertex cannot be reconstructed



Using only some of the tracks we are going to “lose” some events and that means

losing electron-tracks